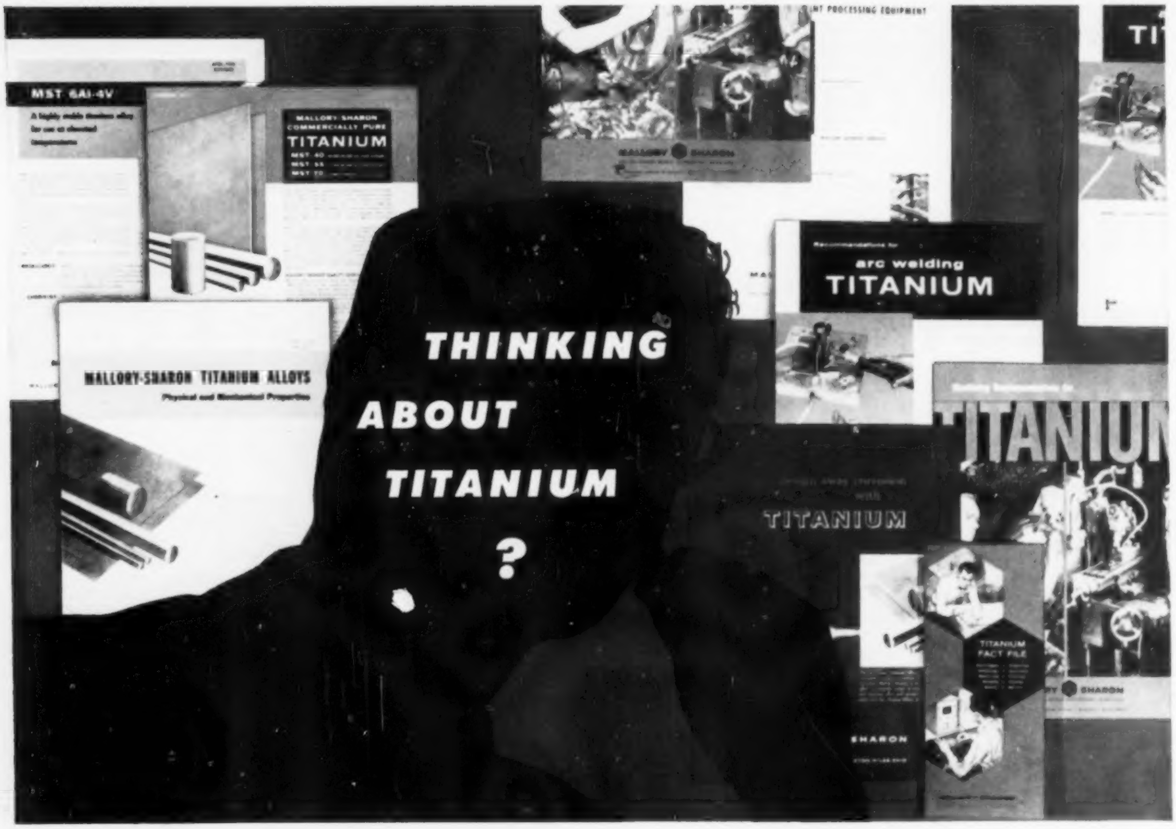
Metal Progress

November 1958



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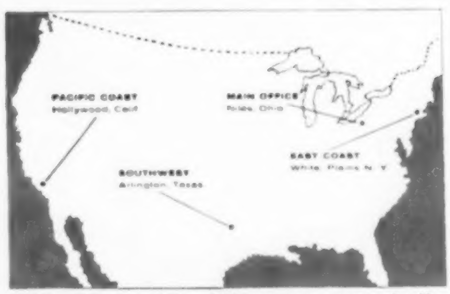

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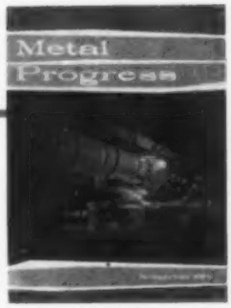

Tests on a jet engine operating above 2000° F. provided the glowing photograph used on the cover. Courtesy General Electric Co. For details, see p. 82.

Table of Contents Continued on Page 3

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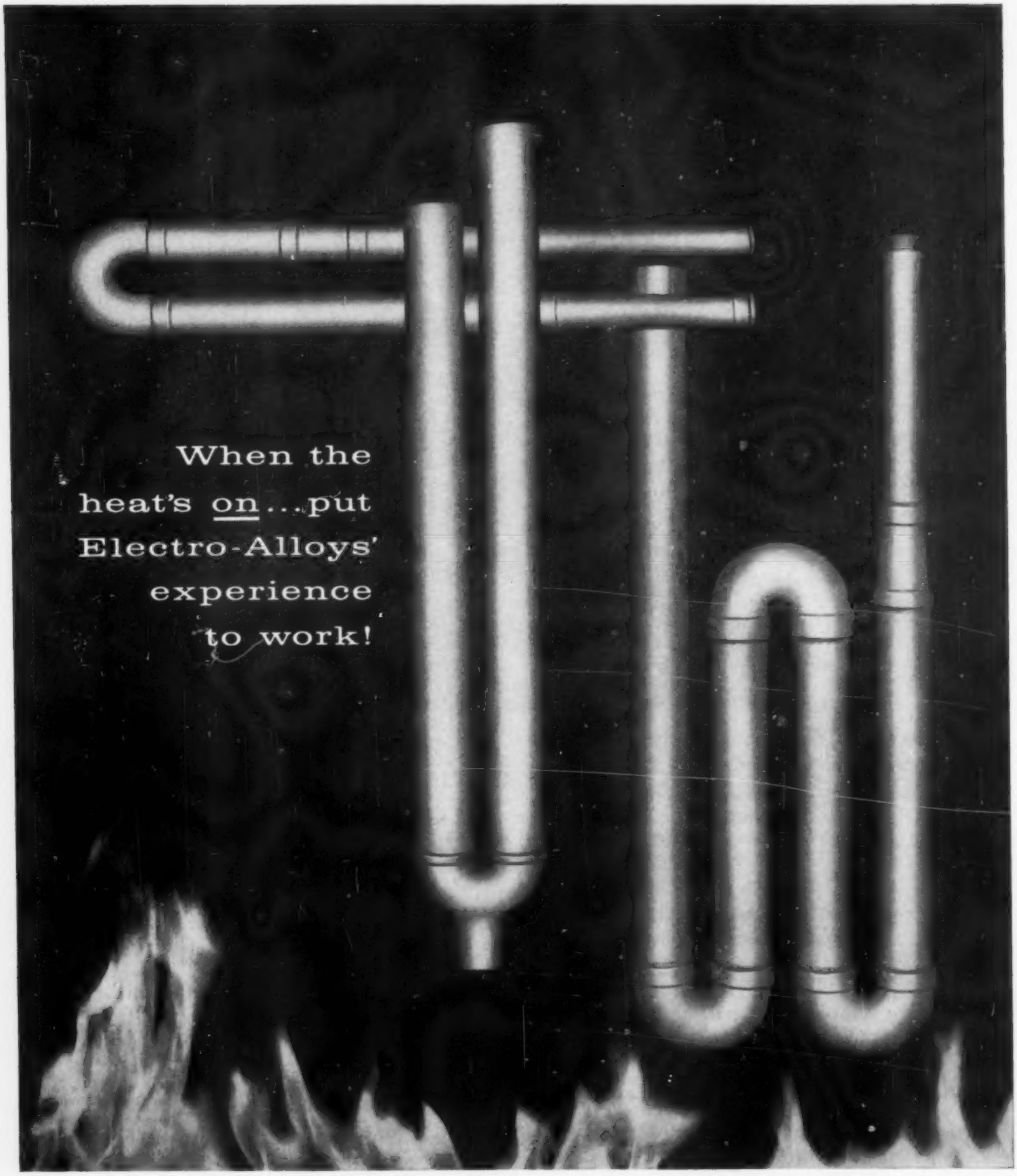
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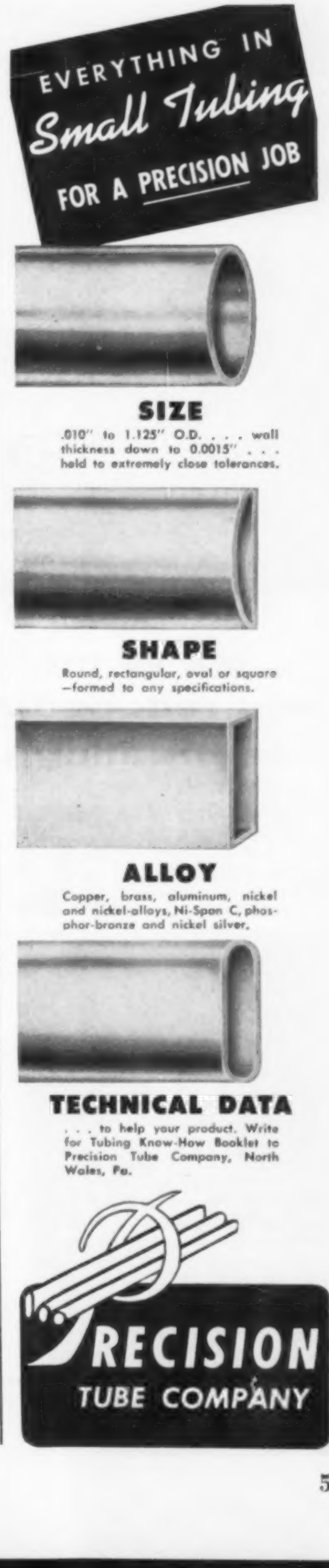


Press Breaks . . .

THIS COLUMN was occupied by the monthly "As I Was Saying . . ." message from Bill Eisenman for many years prior to his death. It was widely read, as we know from many Eastman readership surveys. It had a folksy touch which can hardly be imitated. Nevertheless it will now be resumed in an effort to bring the editors and the readers a little closer together as human beings. A magazine like Metal Progress doesn't just happen – obviously it is the result of coordinated efforts of artists, writers, editors, advertising men, engravers and printers. Maybe it will be worth while to record here incidents which illustrate this truism.

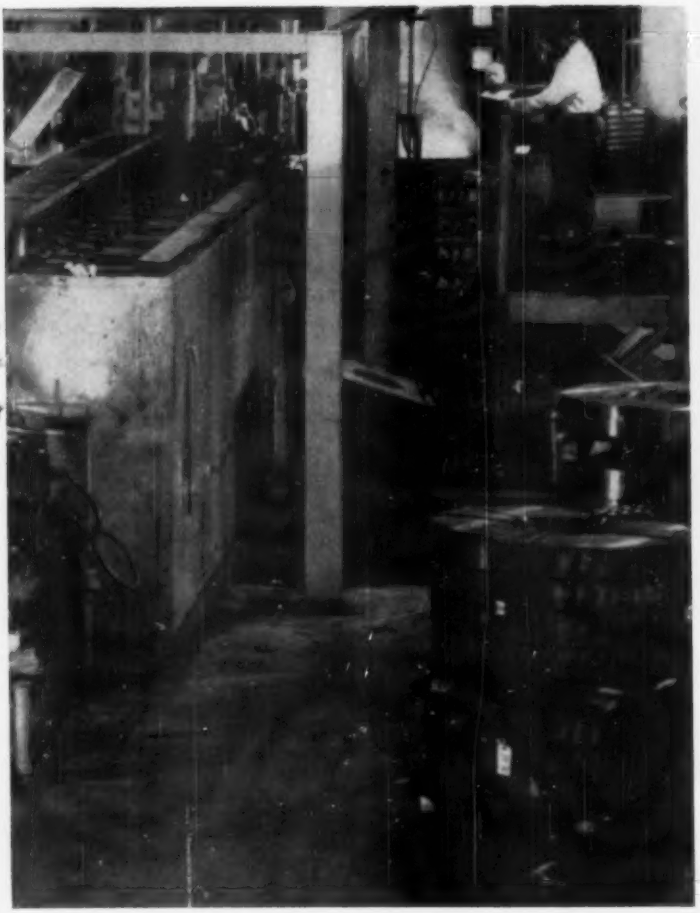
Recently four of us – Ernest Thum, Allen Gray, Marjorie Hyslop and Floyd Craig (and if you want to know what each one's job is just turn to the masthead on page 5) – went from home office in Cleveland to Sheraton-Cadillac Hotel in Detroit to attend a meeting of the Society of Business Magazine Editors. A simple trip, you might say, but that brings up one expensive bane of editorial existence, namely, travel. Short trips of 100 to 150 miles have been all-but-abandoned by the railroads; they're too short for air lines to schedule many flights, and too long to drive without using up a lot of energy. So we went up in four different ways and times, having four different chores in addition to the Editor's Conference. Gray went up by railroad a morning ahead – O.K. Marjorie Hyslop's plane was cancelled – "engine trouble in Pittsburgh". Thum's afternoon plane ran into heavy weather, and he spent just 10 min. short of 5 hr. enroute from Cleveland office to Detroit hotel. Craig drove up – 3 hr., 30 min. He asked us to drive back with him; luckily we didn't for he ran into car trouble! Instead we three took the evening "Mercury", the surviving N.Y. Central train on this run, and enjoyed a good drink, a good meal, and a good deal of shop talk enroute. Total time, hotel to office, 4 hr., 20 min.

Another of our tribulations is getting each page ready to be printed. Our printer (Kable Printing Co., Mt. Morris, Ill.) is 450 miles west, and normally we keep the airlines busy flying page proofs back and forth. Usually this system works, but there are times when it falls down. During preparation of the October Show issue, for instance, all copy was ready. and at Floyd Craig's office for layout in good time. But he got sick. Result – the editorial pages were delayed until no time remained for our standard procedure. Consequently, one of the assistant editors, Carl Weymueller, had to spend three days at Mt. Morris (pop. 2700) revising and okaying pages for each of the three editorial forms. He recommends the town as a wonderful place for a vacation if you want a good rest.

While in Detroit, for the Editor's meeting, Allen Gray spent some time at the convention of the American Rocket Society. You couldn't miss the fact that there was a rocket meeting in town because a variety of missiles were displayed in the streets. Anyway he happened in a session where General Trudeau, Army research chief, was unveiling the recovered Jupiter nose cone. It was fired from Cape Canaveral, Fla., on May 18 and survived the terrific heat of plunging through the atmosphere at the end of a 1500-mile space trip. The Jupiter shot was so accurate that a Navy ship had it on board within 2 hr. after the missile was fired. The nose cone is a fairly good sized object as you can see from the cut – it looked to be some 8 or 9 ft. high although no information was given on its dimensions (or composition either, for that matter).

General Trudeau commented that we are faced with a serious problem of lead time it takes to develop and produce a new missile. Today, it's of the order of 8 to 10 years for us which is unacceptable in face of the Soviet lead time of about 5 years. Certainly something for all of us to think about – missiles or otherwise.

THE EDITORS



EASY ELEMENT REPLACEMENT FROM UNDERNEATH is being accomplished here by Mr. J. A. Boehmer, foreman in charge of furnace maintenance. This easy replacement—without shutting down the furnace—and easy inspection is one reason why Mr. Boehmer would install GLOBAR Delta elements in future furnace installations.

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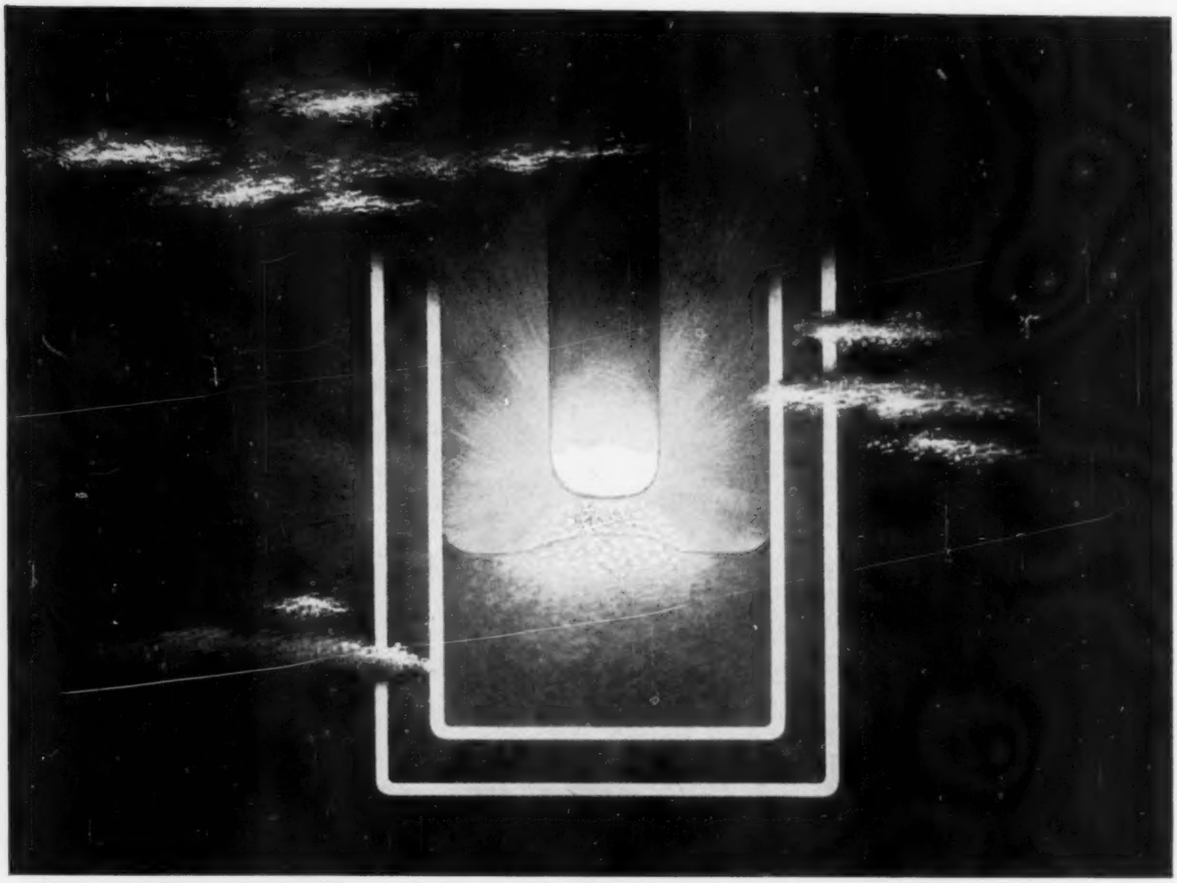

The role of Sylvania consumable electrodes in arc-cast

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Don Nulk, Senior Materials Engineer, Tapco Group, Thompson Products, Inc., for example.

One of his many responsibilities is jet engine blades. He heads up the metals engineering team that deals constantly with the ever-changing factors of design, metalworking and research dictated by ever-increased performance and load demands.

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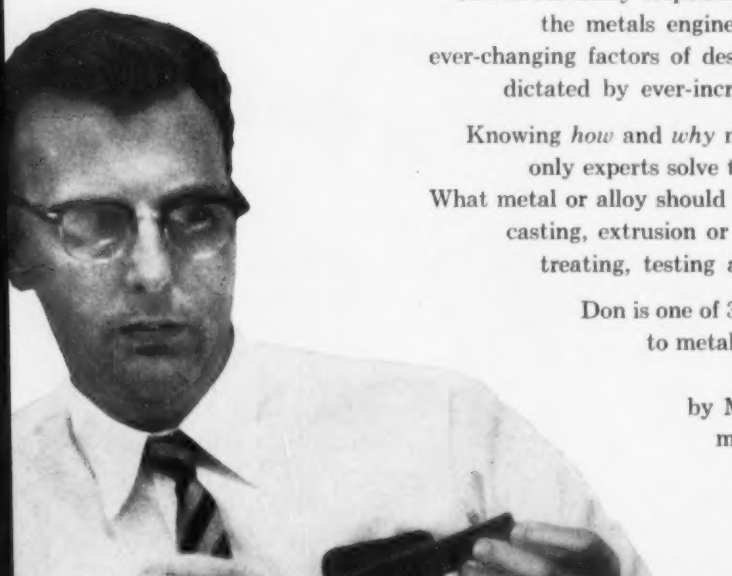
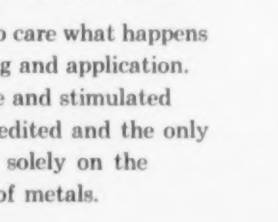
Don is one of 30,000 metals engineers who care what happens to metals—in production, processing and application. They are kept up to date and stimulated by Metal Progress, brilliantly edited and the only magazine that concentrates solely on the engineering aspects of metals.



Donald E. Nulk, Senior Materials Engineer, Tapco Group, Thompson Products, Inc., is responsible for metals and other materials engineering and experimental production.



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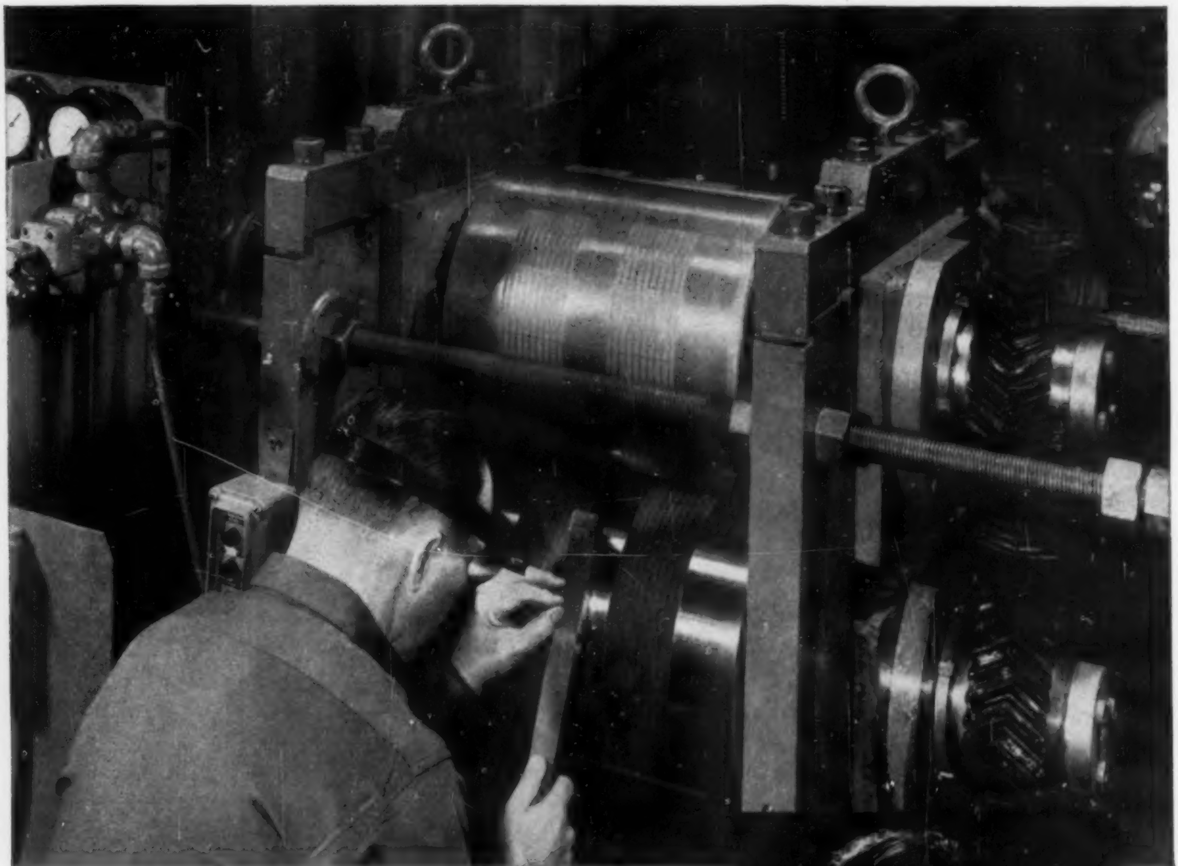

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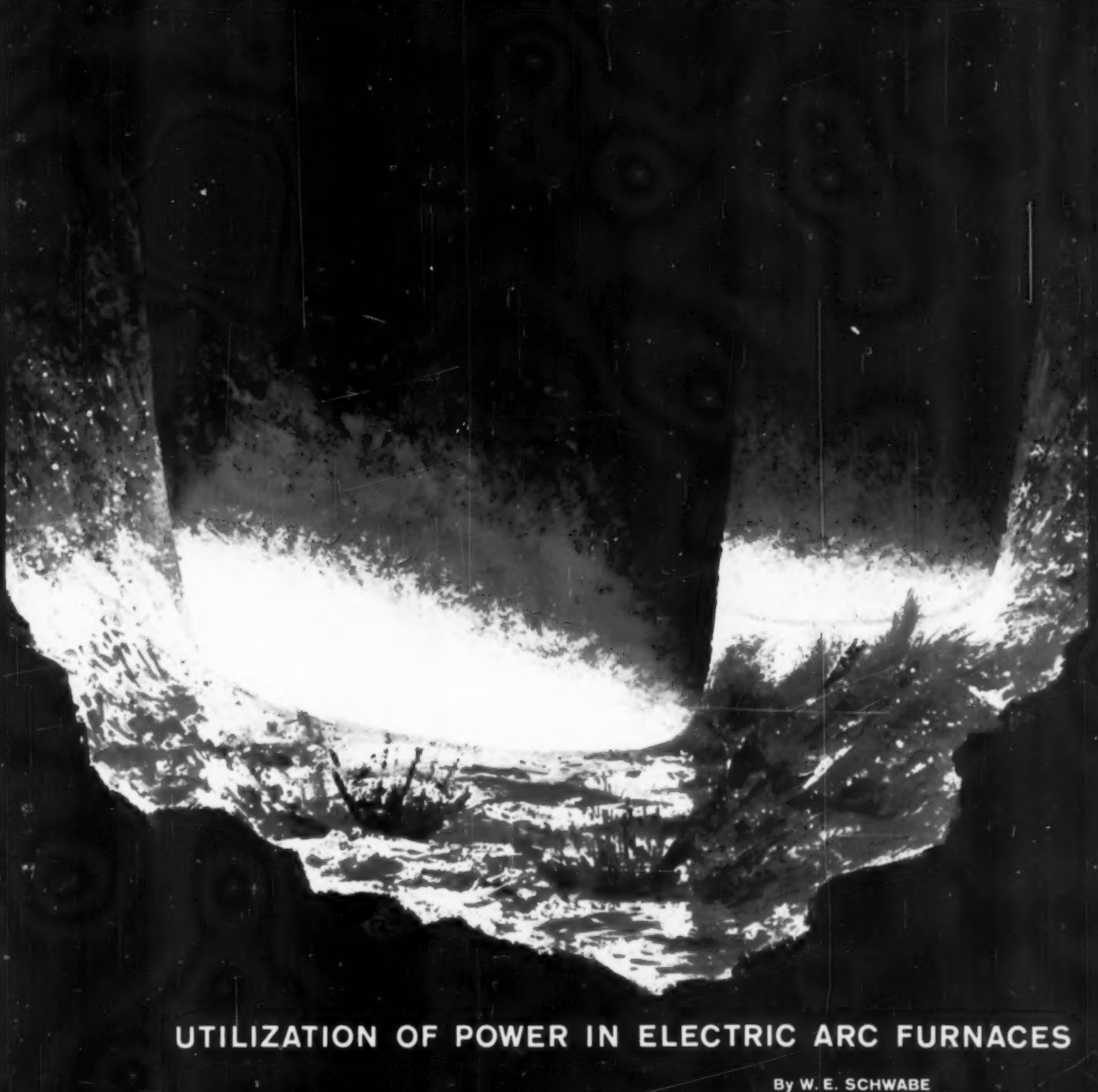


UTILIZATION OF POWER IN ELECTRIC ARC FURNACES

By W. E. SCHWABE
Product and Process Development Laboratory
Niagara Falls, N.Y.
NATIONAL CARBON COMPANY
Division of Union Carbide Corporation

UTILIZATION OF POWER IN ELECTRIC ARC FURNACES

By W. E. SCHWABE
Product and Process Development Laboratory
Niagara Falls, N. Y.
National Carbon Company • Division of Union Carbide Corporation

This paper is an attempt to present some of the factors that influence the economics of electric steel furnace operation from the standpoint of utilization of power and power equipment.

Emphasis is put on the operation of an electric furnace with optimum currents. It is shown that optimum currents in the three phases can differ considerably because of electrical asymmetry of the furnace circuit. Furthermore, the electrical conditions for each phase change during melt-down because of changes in the arc characteristics. This requires a continuous correction of the optimum current during this period.

Because of the space limitations of this publication we have skimmed the surface of some major factors contributing to the utilization of power in electric arc furnaces. It is fully recognized that a certain amount of additional information is desirable and if this article arouses sufficient interest, we will provide a treatise on this subject at a future date.

Introduction

The electric arc furnace has established itself as one of the most effective production tools in the steel industry during the past 50 years. Highest concentration of heat combined with quick regulation, utilization of energy at efficiency levels unknown in other steel making processes, contamination-free melting and refining, flexibility, as well as easy starting and shutdown, are a few of the many reasons for its universal adoption in the steel making trade.

The most remarkable trend over the years has been the call for larger and larger furnaces requiring parallel efforts on the part of the suppliers of electrical equipment and electrodes.

From an engineering point of view, design and development of electric arc furnaces require a unique cooperative effort of metallurgical, mechanical, and electrical engineering, including application of heat transfer physics, refractory, and electrode technology. The trial and error methods of the early days have gradually vanished and have made room for application of scientific and engineering principles both in design and operation of electric arc furnaces.

It is the purpose of this discussion to review some of the pertinent problems of electric steel furnace operation partly in the light of recent research and development work. Special emphasis is put on the problem of utilization of power in existing installations which is not only of importance in view of lower power cost per ton of product, but also in higher melting rates.

Principles of Power Utilization

Melt-down – It should be stressed that it is, in practical operation, often difficult to measure the exact amount of energy consumed for melting, because the cut-off period between melt-down and refining is a variable.

Theoretically, approximately 330 KW hours are needed to melt one ton of cold scrap (270 KW hours to bring it to its melting temperature and roughly 60 KW hours to liquefy the metal). If the melted scrap is to be superheated, an additional 8 to 12 KW hours per 100°F are theoretically necessary.

In practice, energy consumption figures are higher due to heat losses of the furnace and power losses in the electrical equipment.

Theoretical figures, in comparison with the ones obtained in practice, provide a yardstick for the degree of utilization of electrical energy in the furnace. However, they should be looked at with caution when the electrothermic heat input is augmented by exothermic reactions such as from the use of oxygen or heat present in the form of charged hot metal.

Examples are shown in Table I of actual and theoretical energy consumption for melting one ton of cold scrap in small, medium and large furnaces.

TABLE I

Furnace	Small	Medium	Large
Theoretical energy per ton.....	330	330	330 KW hrs. per ton
Actual consumption	475	440	400
Melting efficiency of furnace...	70%	75%	82.5%

Refining—It is obvious that an energy efficiency criterion cannot be applied to the refining period because the energy to be supplied during refining merely serves the purpose of balancing the heat losses of the furnace. The power required for this phase is only one-third to one-fifth of the power required for melt-down.

Factors Influencing Heat Economy – Conduction, convection and radiation are the primary factors contributing to furnace heat losses. The condition of the refractory largely determines the extent of these losses. Newer refractories in good condition tend to conserve heat, worn refractories toward the end of a cycle tend to promote heat loss. Other important contributing factors are open doors, roof ports, etc.

Table II shows the relative increase of total heat losses of the furnace during the refractory life of one roof cycle.

TABLE II

Heat Losses

New roof — new lining................	1.00
After 1/3 roof life....................	1.05-1.10
After 2/3 roof life....................	1.10-1.20
At end of roof life....................	1.30-1.50

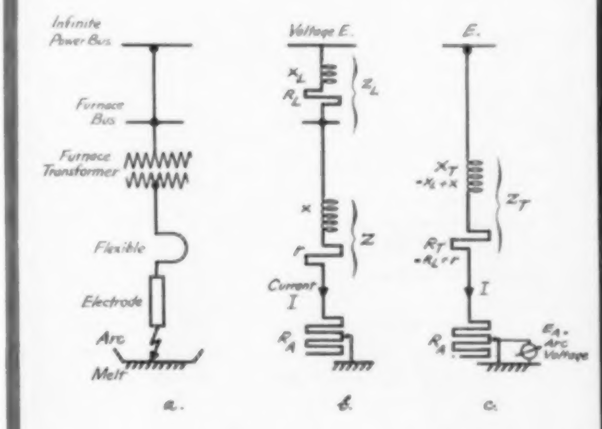
The following basic conclusion can be postulated:

During Melt-Down the heat input should be as high as possible in order to increase the melting rate. Time is an important element since every minute of "power-off" intervals lowers the melting rate. Power should be regulated in accordance with principles to be discussed later.

During the Refining period the time factor exclusively dictates effective operation. Waiting periods should be minimized and reaction and slag work accelerated.

Fundamental Arc Furnace Circuit – The enormous concentration of power in the arc requires a stabilizing element in the circuit. In other words, the current from a power source before it reaches the electrode tip where the arc is initiated, must pass through an impedance. Without an impedance the arc current would "run away" and would increase to an infinitely high value which no power source or conductor would be able to sustain. Therefore, this series or "ballast" impedance acts to limit the arc current. In large furnace installations the ballast is delivered by the inherent combined impedance of the transformer, bus work, flexibles and electrode arms. In small furnace installations supplemental reactors are added on the high voltage side of the furnace transformer.

Figure 1-a illustrates a basic circuit diagram of one phase of the furnace circuit. The equivalent circuit diagram is shown in **Figure 1-b** and a concentrated version in **Figure 1-c.** In this circuit the arc resistance R_A is a variable and is controlled by positioning the electrode relative to the melt. It can be zero when the electrode contacts the melt, or it can reach infinity when the arc is extinguished. Consequently, the current may be high (short circuit) or zero (open circuit). The arc voltage spans the range from the full transformed line voltage (open circuit) to zero (short circuit).



Fundamental Arc Furnace Circuitry and equivalent Circuit Diagrams

FIGURE 1

Fundamental Electrical Characteristics—It is difficult to arrive at maximum arc power by way of metering arc voltage and current because the arc voltage, that is the potential difference between electrode tip and melt, is not readily accessible except for short time probe measurements. Furthermore, certain physical peculiarities of the arc voltage must be considered for this purpose. There is, however, an indirect approach to the problem which can be readily understood by means of a graph representing all the electrical data involved. This is shown schematically in **Figure 2.** This diagram refers to a constant input voltage E_0 (represented by the infinite bus voltage or for practical purposes the plant bus voltage). The arc current at a given voltage tap on the transformer serves as X-axis. By raising or lowering the electrodes, it can be varied from zero (arc extinguished) to its short circuit value. Over this range the arc voltage varies from its initial value of the open circuit voltage at no arc current to zero when the arc is shorted out. The coordinates of this diagram are purposely layed out as percentages so that it can serve as a guide for any specific furnace.

A wattmeter connected at the primary where the voltage remains constant over the range of arc currents would measure the total power input to the furnace and give readings with a distinct maximum as shown in curve N_B. A power factor meter would show the curve PF, and a VAR meter the curve N_B. Total power (N), power factor (PF) and reactive power (N_B) are interrelated with each other and the current. One cannot be changed without influencing the other. These relationships hold true for any furnace if the primary voltage is constant.

Optimum Current — *The maximum of the useful power in the arcs occurs at a current which is considerably smaller than the current that gives maximum circuit power.*

This fact is sometimes overlooked in furnace practice, and the electrode regulators are erroneously set for maximum circuit watts instead of for maximum useful watts. This definitely constitutes a waste of energy, because the useful power at that point is lowered against optimum conditions. In the case of a furnace with a short circuit power factor of 25%, the useful power in the arcs would be only 74% when the total power input is 100%. The corresponding optimum condition would be 77.5% useful power at 96.8% total input. In other words, by not using optimum conditions the heat input is reduced by 3.5% with increase of the power consumption by 3.2%.

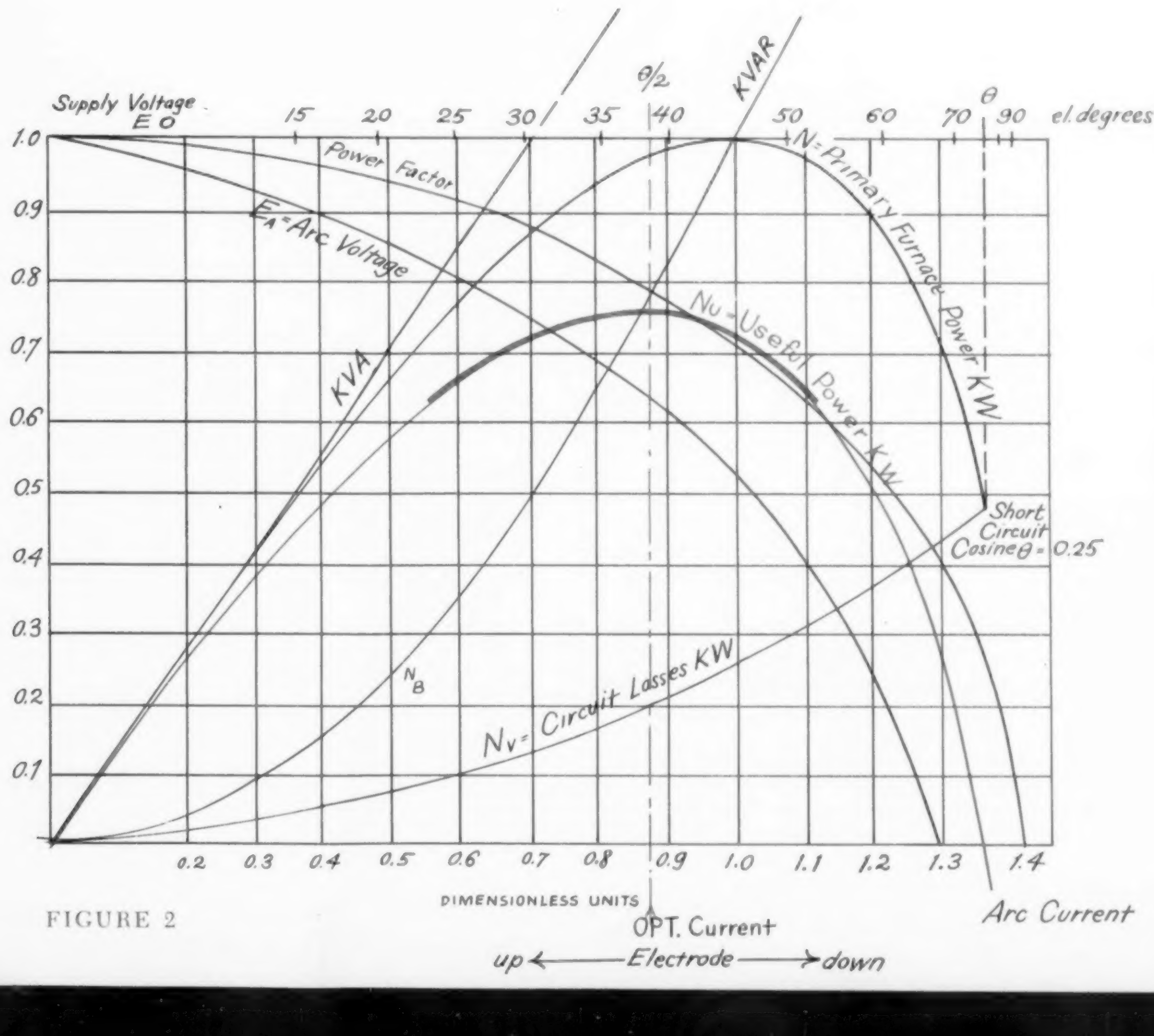


FIGURE 2

While the reactance X of the circuit does not consume kilowatts, the resistance of conductors, flexibles, and electrodes is heated by I^2r heat. The rate of lost power along the path of the current is a function of length and cross-section, which vary considerably from furnace to furnace. A very convenient common denominator is the ratio between the circuit (loss) resistance r and the circuit impedance Z (exclusive of the arc). This ratio r/Z is the cosine θ or the power factor when the arc is shorted by lowering the electrodes in the melt. (Short circuit power factor.) For medium and large size furnaces this short circuit power factor ranges from 15 to 30%, 25% being a good average. (The short circuit current lags the voltage in this case by approximately 80 electrical degrees.) This angle θ and its corresponding power factor (or cosine) give a valuable hint as to optimum current operation: it can be shown that the phase angle ϕ at optimum current should be one half of this short circuit phase angle θ, for example, $80/_2 = 40$ electrical degrees. The optimum power factor ($= \cos \phi$) in this case would be approximately 76 p.c. The curve for the useful arc power and the corresponding optimum current for this condition ($\cos \theta = 0.25$) are also shown in **Figure 2**.

Application of Optimum Current Principle for Three Phase Furnaces – The principle of optimum current holds true for any arc in single or multi-phase systems as long as each arc circuit is considered separately.

Electric steel furnaces use three phase power, and the three circuits exercise a certain influence upon each other.

There would be no need for this part of our discussion, if there were a perfect electrical symmetry in the furnace circuit; in that case each phase would show the same behavior, and optimum conditions would be identical in all phases. In conventional furnace design these requirements are not fulfilled because:

1) The current path of the outer phases is normally longer than that of the center phase because the center phase electrode is closer to the transformer. Consequently, resistance and self-inductance in the outer phases are somewhat larger than that of the center phase. (In some cases the electrode spacing triangle is reversed, and B phase is longer.)
2) The effective resistance especially in the flexibles depends to a certain degree on the current distribution in the individual flexible cables influenced by magnetic fields and temperature non-uniformities.
3) Similarly, the self-inductance of each path depends on the geometry of the conductors, and on proximity effects of adjacent steel structures.
4) The most important contributor to electrical non-symmetry, however, is the effect of mutual inductance between the conductors.

Mutual Inductance Between Conductors – Mutual inductance is influenced by the geometrical arrangement of the conductors.

In an arc furnace of conventional design the three high current conductors are arranged side by side with equal spacing "a" (**Figure 3**) so that their geometrical centers C_1, C_2, C_3 are in one plane P.

It is obvious that the mutual inductance between No. 1 and No. 2 or No. 2 and No. 3 is larger than between No. 1 and No. 3. In other words, there is a difference in electro magnetic coupling between the three phases. One fundamental law governing coupled circuits states that the circuit whose current leads by less than 180 electrical degrees transmits some energy upon the circuit whose current lags. (If coupling conditions were identical between the three phases, the transmitted energies would be equal in all three phases; phase 1 would transmit to phase 2, phase 2 to phase 3, and phase 3 to phase 1 and the net effect would be zero).

In this case of electrical non-symmetry, however, the difference of mutual inductance between No. 2 vs. No. 1 phase and No. 3 vs. No. 1 phase induces a voltage in No. 1 phase in opposition to the current in No. 1 phase. This counter emf acts so as to increase the effective resistance of phase No. 1 conductor. Conversely, phase No. 3 conductor receives an induced voltage which is in phase with No. 3 phase current, and its effect is a decrease of effective resistance in this conductor. Phase No. 2 (center phase) is not affected by this phenomenon.

For these reasons, phase No. 1 delivers less power and is called the "cold" or "dead" phase. Phase No. 3, called the "hot" or "wild" phase, delivers more power; however, the center phase power is still larger than No. 3 phase because of lower self inductance and resistance. The sum of the optimum power in all phases under these conditions is identical with the sum that could be obtained at perfect electrical symmetry, however, the uniformity of heat distribution in the furnace is somewhat disturbed.

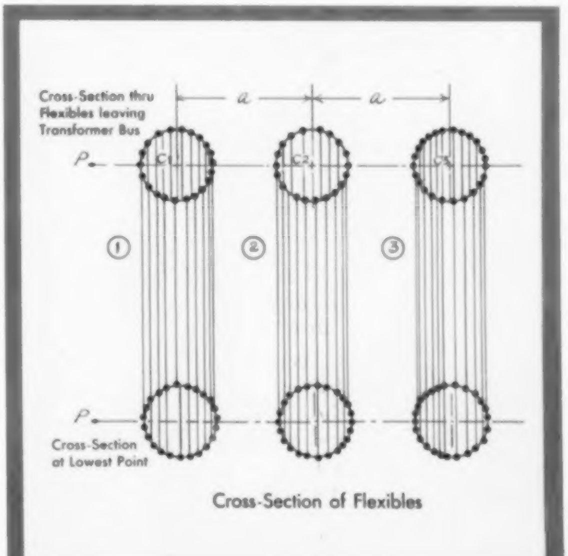


FIGURE 3

Importance of Phase Sequence – During investigations in the field, it was found on several occasions that the

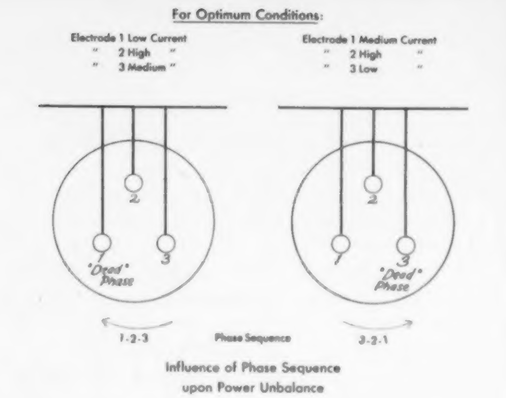


FIGURE 4

current settings, although approximately adequate in their magnitude, did not correspond to the phase sequence and consequently the melting rate was too low and the power consumption too high.

In the preceding section on mutual inductance, it was assumed that we have electrical phase sequence 1-2-3 or A-B-C. The principle of optimum current in each phase dictates that the individual arc resistance should be made equal to the sum of all series impedances in that phase exclusive of the arc. This requires a higher optimum impedance and consequently lower optimum current in phase No. 1; and a lower optimum impedance and higher optimum current in phase No. 3. These conditions are reversed if the electrical phase sequence is 3-2-1 with the center phase not being affected; phase 3 would be underpowered (dead phase) and phase 1 would be the "hot" phase. See **Figure 4.**

Improving Electrical Balance of Circuits – Electrical balance leads to uniform heat generation, reducing of hot spots in the refractory, and equalized electrode consumption in the three phases. Practical considerations restrict complete balancing of phase impedances in conventional furnaces by locating flexibles and the rest of the high current conductors on the corners of an equilateral triangle. There are, however, several possibilities that can result in improvement over present conditions:

a) Flexible bundle conductors can be replaced by water cooled cables of considerably smaller overall cross-section. These can, over a part of their length at least, be arranged in a triangular pattern.

b) If the flexible bundle of the center phase only is replaced by one water cooled cable and the outer phase brought closer together, coupling between the outer phases can be improved.

c) Water cooled cables can be arranged as shown in **Figure 5.** The outer phases carry the current in two or more parallel small water cooled cables, whereas, the center phase has only one heavy water cooled cable.

d) In cases where the conductors of the high tension feeder line leading to the steel plant or to the furnace transformer are electrically unbalanced (the three conductors in one plane) the "dead" phase of the feeder should be connected to the center phase of the transformer. This tends to improve the overall balance.

e) Unequal phase voltages resulting from a furnace transformer with purposely unbalanced secondary voltages (higher voltage for the dead phase) are restricted to the rare cases where furnace transformers with a secondary Y connection are used.

f) Lengthening the center phase flexible bundle so that an equilateral triangle is obtained at the lowest point has shown improved balance.

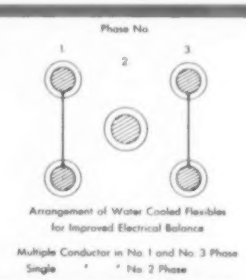


FIGURE 5

Influence of Harmonic Distortion of Arc Currents – Arc power is lowered by the influence of harmonic distortion. Harmonic distortion is caused by the discharge mechanism of the arc. It was found that arc currents at start of melt-down display a remarkable degree of harmonic distortion. As the average temperature of the charge increases during melt-down, the degree of distortion recedes gradually and during the latter part of melt-down, the current pattern assumes a sinusoidal shape. During the initial erratic period of melt-down, practically each half cycle of each phase current shows a different pattern.

What is the effect of harmonic distortion upon the optimum current concept? Optimum conditions, that is maximum heat generation in the arcs, exist if the external (or circuit) impedance equals arc resistance. The greater part of the circuit impedance is inductive, and is proportional to the power frequency, for example, 60 cps.

The Fourier analysis of currents showed that they contained an appreciable amount of higher harmonics which combined would be effective as an equivalent sinusoidal power frequency of up to 75 cps. Consequently, the inductive part of the series impedance increases with harmonic distortion paralleled by a minor increase of the resistance component due to a more accentuated skin effect. The increase of resistance by skin effect is, however, negligible for practical purposes.

Therefore, distorted currents increase the ballast impedance and in order to establish optimum conditions the arc resistance must be increased too. This also results in lower arc power. This presents a difficult task as far as electrode regulation is concerned.

Arc Stability and Maximum Heat Generation – From the viewpoint of maximum heat input to the furnace it is important that the resistance of the arc, and consequently its length be maintained as constant as possible. There are several factors that tend to disturb an existing arc by changing its length during melting:

1) Erratic movement, essentially caused by gravity, of that part of the charge which is actively engaged in providing the foothold of the arc.
2) Turbulence of the surface of the molten pools under the arcs.
3) Arc flare caused by electromagnetic forces of the arc currents.

Modern electrode regulators are capable of correcting a disturbance by re-establishing the desired current in a short time. This holds true, especially for erratic movement. Arc regulation involves rapid raising or lowering of the electrode column without overshooting. Short-timed variations of the arc length caused by melt-turbulence and arc flare occur too fast to be fully corrected by the regulator. Each deviation from the optimum current value leads to a reduction of the useful power in the arc.

Power Characteristics of Large Furnaces

A typical practical application of the fundamentals of the power circuit and regulation of power, discussed in the preceding sections, was made on a 130-140 ton furnace using 24″ diameter graphite electrodes and a nominal high tap voltage of 465 volts between phases. The electrical phase sequence at the electrodes is C-B-A.

The electrical data of the furnace were determined experimentally by means of special instrumentation. At a low tap voltage the three electrodes were lowered in the melt, and readings of voltage, current, and phase angle were taken for each phase. These data yielded the values for the furnace impedance and power line impedance between the "infinite bus" and the steel plant bus.

The corresponding values of the furnace impedance for the highest tap voltage were calculated. (This could not be done experimentally because the high short circuit currents would have tripped the circuit breaker almost instantaneously.)

With these values, the characteristic curves for high tap were calculated as illustrated in **Figure 6. Figure 6-c** is most interesting from the standpoint of maximum heat input to the furnace confirming the theory that the three phases have power maxima occurring at three different currents. The highest power is obtained in the center phase B, followed by a slightly lower power in A, whereas, C phase power is distinctly lower. Therefore, the currents in the three phases should be adjusted to these optimum conditions. It is quite obvious that the sum of power in all three phases would be lower, if for example, the furnace were operated with the same current in all three phases. On the other hand, if the same power in all three phases is desired, power in phase A and B would only partly be utilized, and the total power would drop considerably.

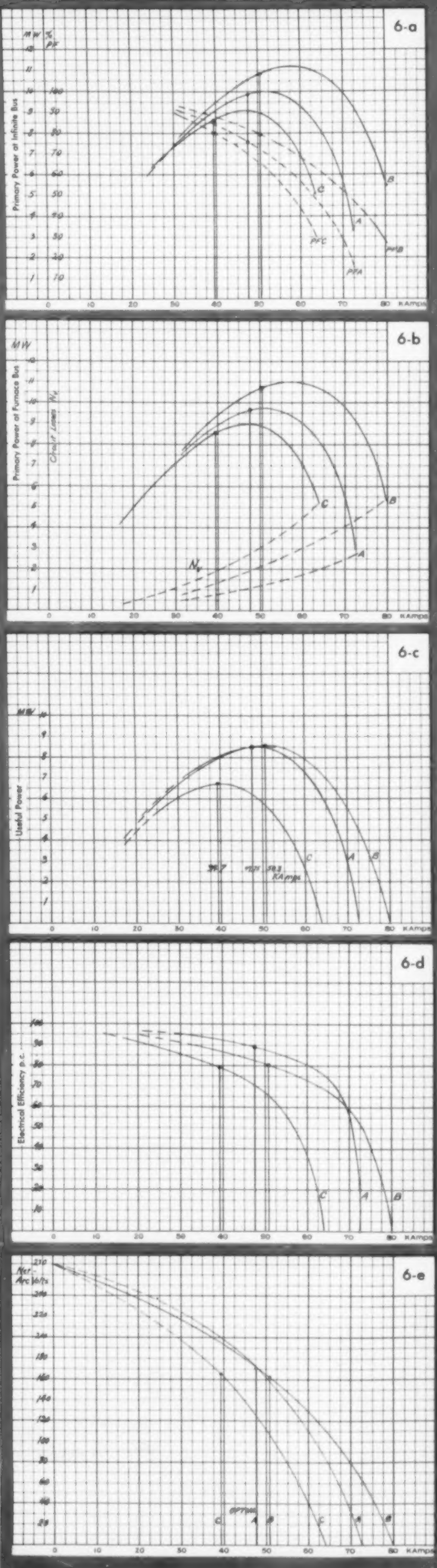


FIGURE 6

This asymmetry is also reflected in the power conditions on the primary of the furnace transformer, and at the infinite bus, as well as in the power factor.

Furthermore, it points to the fact that diagrams depicting the combined three phase power plotted against a common current have no meaning unless this current includes some definition on the degree of asymmetry in the three phases.

The electrical efficiency as defined by the ratio between useful power **(Figure 6-c)** and primary power **(Figure 6-b)** at the furnace bus, is shown in **Figure 6-d**. It is affected by electrical asymmetry, and drops off with current increasing, due to the increase of circuit losses with the square of the current.

As far as heat transfer from the arc and refractory are concerned, **Figure 6-e** reveals the influence of arc currents upon the arc voltage and arc length. The advantage of having almost identical arc voltages (= arc length), between electrode tip and melt when using optimum condition in each phase is quite obvious.

Conclusion

These scientific and engineering principles from both theoretical and practical aspects point up the fact that highest melting production rates are obtained with optimum currents. However, it should be stressed that increased efficiency of energy conversion from electricity to heat in the furnace can be achieved by using currents that are somewhat lower than optimum current. This results in lower power input and slower melting. The choice between fastest melting or increased efficiency of energy conversion depends strictly on operational factors.

Also it should be pointed out that electrodes (the final link between power station and arc) withstand extreme thermal and mechanical conditions, and perform their duty at an efficiency of 98% and above.

All of these relationships provide a utilization of power in electric furnaces which is superior to combustion type furnaces: electric steel melting requires approximately ⅓ of the BTU's needed in an open hearth furnace.

It is hoped that this presentation will stimulate interest in the many factors contributing to the utilization of power and power equipment in electric arc furnaces.

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APPLICATION and EQUIPMENT new products

Nitrogen Generator

A new generator for the automatic production of nitrogen atmosphere by combusting a mixture of air and natural gas, or any manufactured gas, has been announced by the Gas Process Div., Lindberg Engineering Co. The atmosphere produced is CO_2 free, dry combusted gas which may be varied from rich to lean ratios. The

unit consists of three separate assemblies interconnected with piping and wiring. The combustion assembly is made up of an exothermic generator with visual flow meters, fire check, combustion chamber, surface condenser, gas separator and water trap. Blowers, heat exchangers and gas booster systems reactivate and cool the CO_2 absorption towers. The absorption assembly consists of three absorption towers filled with molecular sieve to absorb CO_2 and water vapor.

For further information circle No. 940 on literature request card, page 48-B.

Titanium Alloys

Mallory-Sharon Metals Corp. has announced four new titanium alloys. MST-2½Al-16V is alloyed with 2½% Al and 16% V. It can be worked in a low strength condition and then age-hardened or strengthened to high tensile strength. In its solution-treated form, this alloy ranges below 65,000 psi. in yield strength, and has elongation in excess of 10%, permitting forming of sheet metal components. An aging treatment increases the ultimate tensile strength to 155,000 to 200,000 psi. MST 821 is alloyed with 8% Al, 2% Cb and 1% Ta. It is arc weldable and has high-temperature strength. MST 185, still in the experimental stage, is being developed to produce high strength in the annealed condition. The last of the new alloys, MST-3Al-2½V has 3% Al and 2½% V, and is intended for high-strength tubing. It is weldable and formable and resistant to corrosion. By suitable age-hardening treatment, tubing can be strengthened after fabrication to an ultimate strength of 120,000 to 130,000 psi.

For further information circle No. 941 on literature request card, page 48-B.

Silver Plating

A new bright-silver plating process has been announced by the American Platinum & Silver Div. The process may be used in plating holloware, aircraft bearings, bussbars, waveguides and jewelry. Equal results can be obtained in both barrel and tank plating. Plating may be done at room temperature. Silva-Brite gives bright finish (100% specular reflection) from flash to heavy deposits. The plate has a hardness of Brinell 135 and tends to age-harden up to 212° F.

For further information circle No. 942 on literature request card, page 48-B.

Molybdenum

High-purity pellets of molybdenum metal are being offered by the General Electric Co. Pellets are sintered powder compacts with a purity of

99.75%. Their minimum weight is 8.0 gr. per cu. cm. and each pellet weighs about 2 oz. Pellets are ⅞ in. in diameter and ⅝ in. high.

For further information circle No. 943 on literature request card, page 48-B.

Thickness and Density Gage

A new noncontacting gage has been announced by Nuclear Systems, a division of the Budd Co. Gammascan can be used to measure and control the thickness of continuously produced materials such as steel plate and can inspect such products as rolled sheet steel, extruded forms and solid fuel for missiles. Gamma radiation from

the machine's shielded cobalt-60 source passes through the material being inspected to a scintillation detector which converts the radiation to an electrical current. Variations in this current are interpreted as changes in material thickness or density. Output is indicated on a meter calibrated in thickness increments and can be fed to a recorder.

For further information circle No. 944 on literature request card, page 48-B.

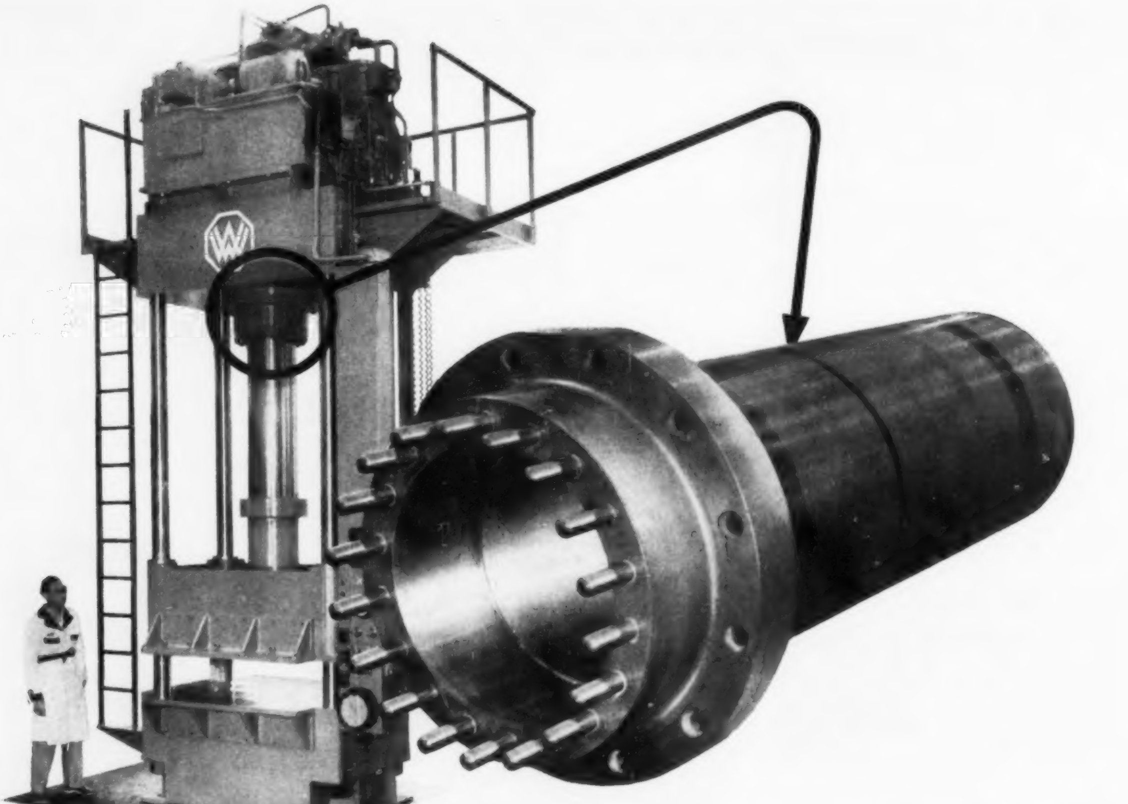
Pre-Formed Electrodes

Twelve new pre-formed electrodes for spectroscopic analysis have been announced by National Carbon Co. This brings the total to 52 different sizes and shapes in stock. Among the new electrodes are pre-formed electrodes ⅛ in. in diameter.

For further information circle No. 945 on literature request card, page 48-B.

Blast Cleaning Barrel

Pangborn Corp. has announced a new heavy-duty 20-cu. ft. Rotoblast



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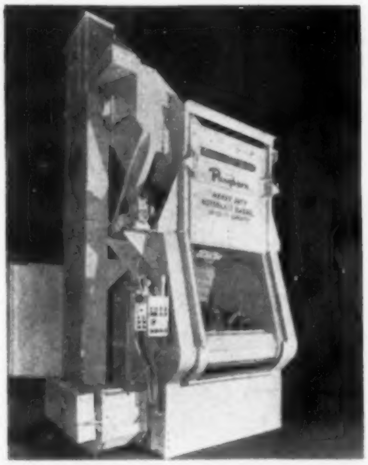


barrel. The high-capacity barrel has a 30 hp. motor, which allows the wheel to throw 50,000 lb. of abrasive per hour. The work conveyor handles loads up to 3500 lb. with single pieces weighing up to 800 lb. each. The 20-GN Rotoblast barrel is 8 ft. 5 in. deep by 11 ft. 10 in. wide and 16 ft. 11⅝ in. high.

For further information circle No. 946 on literature request card, page 48-B.

Low-Temperature Cabinet

The American Instrument Co. has announced a dry-ice operated low-temperature cabinet with a temperature range of +200 to −120° F. The cabinet is divided into two sections, a testing chamber located on one end and a dry-ice compartment on the other. The lid is fitted with a Thermopane window for observing samples under test. Two sizes of cabinets are offered, one with a dry-ice capacity of 60 lb. and workspace dimensions of 24 by 24 by 24 in., and the other

with a 50-lb. dry-ice capacity and work dimensions of 18 by 16 by 20 in. The time required to reach −100° F. from room temperature is approximately 90 min.

For further information circle No. 947 on literature request card, page 48-B.

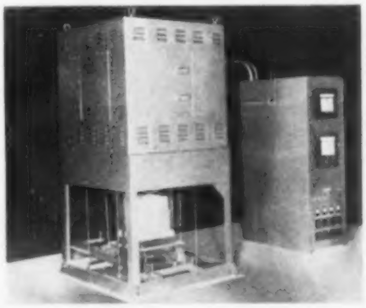
Microscope

Edmund Scientific Co. has announced an industrial pocket microscope with adjustable power of 20, 40 and 60 magnifications. It is 5⅝ in. long. A milled ring near the objective lens is turned to bring objects into focus. Chromium tip reflects light on objects viewed.

For further information circle No. 948 on literature request card, page 48-B.

Electric Furnace

Harrop Ceramic Service Co. has announced a new electric furnace, specially adapted for the control of atmospheres and temperatures. The furnace housing is completely sealed to insure retention of the atmosphere. Setting space is 12 by 12 by 16 in. Elements of the nonmetallic resistor-type are lightly loaded. The upper banks of elements can be controlled independently of the lower banks,



either by manual adjustment or by separate instrumentation. Furnace operates up to 2800° F. and is available in all common voltages, single or 3-phase, 16 kw. The elevator-type hearth is raised and lowered by a reversible motor drive, and the hearth travels on rigid vertical guide rails.

For further information circle No. 949 on literature request card, page 48-B.

Thermocouples

The Bristol Co. has announced the Armorox thermocouple for measuring temperatures up to 2000° F. at pressures up to 50,000 psi. This metal-sheathed, ceramic-insulated thermocouple may be bent around twice its own diameter to get into out-of-the-way places. The sheathing is available in stainless steel and Inconel in diameters from 1/16 to ¼ in. and lengths to 30 ft. Wire down to AWG No. 30 can be used. Thermocouples are available in Chromel-Alumel, iron-constantan, copper-constantan, and other materials.

For further information circle No. 950 on literature request card, page 48-B.

Coating-Thickness Testing

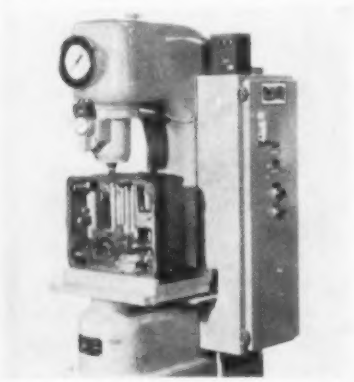
A new probe for use with its coating thickness tester has been announced by Unit Process Assemblies, Inc. The right-angle probe permits

nondestructive measurements of coatings and films on the inside diameters of pipes, bores in castings and such, down to ¼ in. i.d. It can measure a variety of metallic and nonmetallic coatings such as plating, anodizing, paint, plastics and ceramics.

For further information circle No. 951 on literature request card, page 48-B.

Hardness Testing

For high-production Brinell hardness testing where locations of the test must be accurate, Steel City Testing Machines, Inc., has announced an interlocking positioner which assures that the workpiece is in position before it can operate. A limit switch



located in the table fixture must be depressed by the part before the knee-actuated cycle-switch becomes energized. Throat depth of the machine is 10 in., the maximum vertical opening is 14 in. and loads from 500 to 3000 kg. can be applied. Colored lights on the machine indicate the relative hardness of the part.

For further information circle No. 952 on literature request card, page 48-B.

Metal Removal Torch

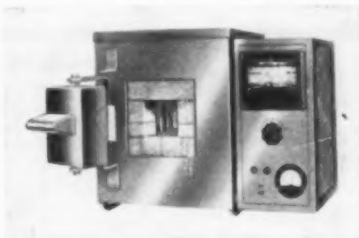
The Arcair Co. has announced a new metal removal torch designed for intermittent applications and for light uses. Among the new features is a

positive air-control valve in the torch handle. By holding the air orifice in the head of the H-2, within 4 in. of the work, the torch can be operated on 40 psi. of compressed air.

For further information circle No. 953 on literature request card, page 48-B.

Laboratory Furnace

A laboratory-size furnace which provides 60 sq. in. of radiation surface has been announced by Blue M

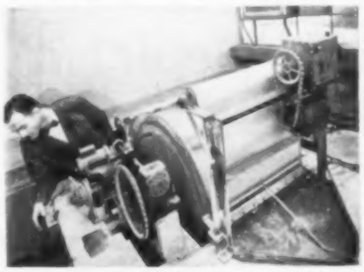


Electric Co. It will produce continuous temperatures to 2700° F. and intermittent temperatures to 2800° F. It uses eight ½-in. diam. Delta Globar elements, vertically mounted, and features an automatic electronic indicator-controller with dual scale range, 13% platinum thermocouple and thermocouple break protection.

For further information circle No. 954 on literature request card, page 48-B.

Zinc Foil

A new, continuous process to produce zinc foil has been announced by American Smelting and Refining Co. Sheets range from 0.005 to 0.001 in. in thickness and 26 in. in width. Zinc is deposited electrolytically from a



zinc sulfate bath onto a revolving drum. The foil is stripped from the drum in a continuous sheet of uniform thickness. The foil will be used in the electrical field.

For further information circle No. 955 on literature request card, page 48-B.

Vacuum Coating

A 72-in. vacuum coater with six stations which hold workpieces up to 22 by 50 in. has been announced by the Rochester Div. of Consolidated Electrodynamics Corp. Pump-down time to attain a normal working pressure of 5×10^{-4} mm. Hg is 5.5 min. The operating range for the LC1-72 is from 5×10^{-5} to 2×10^{-3} mm. Hg.

For further information circle No. 956 on literature request card, page 48-B.

Thermocouple Wells

Claud S. Gordon Co. has announced a new line of drilled thermocouple

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ALLOY Useful Temperature Range	TENSILE DATA		RUPTURE DATA (100 Hrs.)	METHOD OF MELTING
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HWD Up to 1000°F	140,000 14% 1050°F	170,000 52% 1050°F	170,000 12%+ 900°F	AIR ARC
†GREEK ASCOLOY Up to 1000°F	135,000 17% 70°F	155,000 56% 70°F	42,000 35% 1050°F	AIR ARC
16-25-6 Up to 1300°F	71,000 33% 70°F	129,000 54% 70°F	42,000 12%+ 1200°F	AIR ARC
A-286 Up to 1350°F	98,000 22% 70°F	150,000 42% 70°F	62,500 7% 1200°F	AIR ARC STERCON
STERVAC 3000 (M-308) Up to 1350°F	121,000 14% 1200°F	134,000 20%+ 1200°F	65,000 — 1300°F	STERCON STERVAC
STERVAC 1000 (Waspaloy**) Up to 1500°F	—	—	36,000 14% 1500°F	STERCON STERVAC
STERVAC 2000 (M-252) Up to 1500°F	98,000 20% 70°F	170,000 22% 70°F	34,000 — 1500°F	STERVAC
STERVAC 5000 (Udimet 500***) Up to 1600°F	— 8%+ 1200°F	175,000+ 10%+ 1200°F	25,000 30%+ 1650°F	STERVAC
STERVAC 4000 (Rene 41*) Up to 1650°F	110,000+ 8%+ 1400°F	120,000+ 12%+ 1400°F	25,000 25%+ 1650°F	STERVAC
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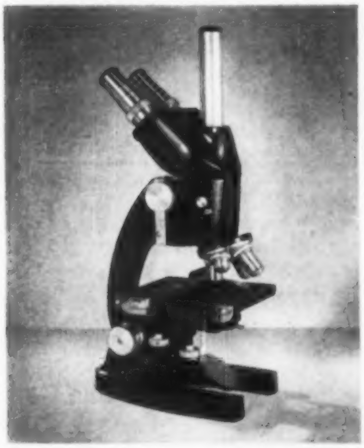
wells, thermometer sockets and thermometer test wells. They are for pressure installations to permit checking or replacing of thermocouple or thermometer without opening the line or vessel. They are made from round or hexagon stock in Type 340 stainless steel, Hastelloy, aluminum, nickel, chromium iron and cast iron.

For further information circle No. 957 on literature request card, page 48-B.

Microscope

Bausch & Lomb Optical Co. has announced a new line of Dynoptic microscopes equipped with triocular bodies. The new microscope contains a monocular tube for camera attachment which allows photomicrography or simultaneous visual observation.

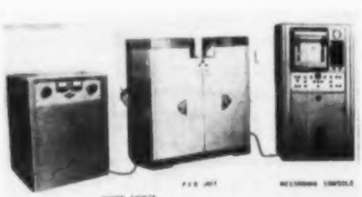


The new instrument allows 80% of the source illumination to be directed to the monocular camera tube. The remaining light is sufficient for visual operation. The triocular body can be rotated over 360°.

For further information circle No. 958 on literature request card, page 48-B.

Metal Analysis

Applied Research Laboratories, Inc., has announced a new direct-reading X-ray fluorescence instrument for analysis of all elements above atomic No. 11. Simultaneous analysis of up to 22 elements in the wave length



range 0.35 to 10.2 A is provided from a single sample. Each element emits fluorescent radiation at a characteristic wave length. Measurement of the intensity of this radiation by various detectors provides quantitative analysis of each element in the sample. The analytical system is composed of three units: the power source, the spectrometer and the recording console.

For further information circle No. 959 on literature request card, page 48-B.

Iron Powder

A high-strength, low-alloy iron powder has been announced by Republic Steel Corp. The new iron powder contains small quantities of nickel and molybdenum. It can be fabricated to develop minimum tensile strengths of 60,000 psi. as sintered and 100,000 psi. when heat treated. Parts may be fabricated with briquetting pressures of 30 to 35 tons to obtain a density of 6.4 gr. per cu. cm., sintering cycles of 2030 to 2050° F. for 45 min. in an endothermic atmosphere and normal heat treating procedures.

For further information circle No. 960 on literature request card, page 48-B.

Ovens

Hevi-Duty Electric Co. has announced a new Circ-O-Therm oven with temperatures to 482° F. Strategically located heaters, fastened

to the outside of the aluminum inner shell, conduct heat to the aluminum inner surface providing fast heat-up as well as uniformity of heat. Round design also increases the natural circulation of air. The oven operates on either 115 or 230 volts A.C. The work chamber of this oven is 13 in. deep by 15 in. in diameter. Three removable aluminum shelves, perforated for circulation of air, are provided.

For further information circle No. 961 on literature request card, page 48-B.

Blast Furnace Brick

A new grade of carbon brick for blast furnace linings has been announced by National Carbon Co. A new manufacturing process consist of

forming bricks in presses and simultaneously baking them at high temperature with high electric currents.

For further information circle No. 962 on literature request card, page 48-B.

Laboratory Furnace

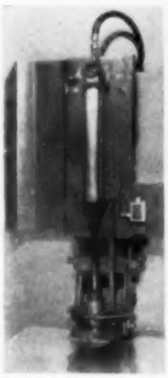
A new laboratory box furnace has been announced by the Laboratory Equipment Div. of Lindberg Engineering Co. The maximum operating

temperature of 1850° F. is reached within 70 min. Effective work chamber size is 4 by 3⅞ by 10 in.

For further information circle No. 963 on literature request card, page 48-B.

Marking

Pannier Corp. has announced self-inking pneumatic vertical markers that were originally designed for printing steel sheets during the shearing operation but which can be used for marking in register on packages, cans, cartons and like objects. The printing head can be equipped for consecutive numbering, solid-die printing or with type holder when different setups are required. The unit is self-adjusting to variable thicknesses of material being printed. The standard printing surface is 4 by 4⅛ in. for solid dies and type setups. The standard numbering device will accommodate up to seven 1-in. characters.



For further information circle No. 964 on literature request card, page 48-B.

Vacuum Furnaces

Two new high-vacuum furnaces have been announced by NRC Equipment Corp. An automatic high-temperature sintering furnace provides a 6-in. diam. by 10 in. high hot zone at pressures down to 10^{-5} mm. Hg and temperatures to 4300° F. The other furnace is designed for melting reactive and refractory metals and for development of high-temperature ferrous alloys. It has a capacity of 50 lb., and features a consumable arc and cold mold.

For further information circle No. 965 on literature request card, page 48-B.

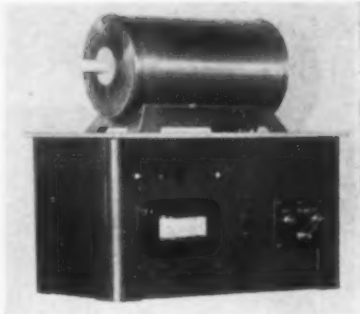
Cleaning and Phosphating

A new material for cleaning and light phosphating of iron, steel or zinc in three stages has been announced by Turco Products, Inc. Turcoat 4185 meets the salt spray and paint adhesion requirements of USA-57-0-2C, Type II, Class C. Applied by either spray or dip, it deposits a phosphate coating of up to 70 mg. per square foot on steel. Turcoat 4185 cleans light soils and removes rust.

For further information circle No. 966 on literature request card, page 48-B.

High-Temperature Furnace

Lucifer Furnaces, Inc., has announced a new series of electric heat treating furnaces. The Series 6055 is made in six standard models with heat ranges to 3000° F. The new Kanthal super element is used. All standard models include an automatic controller, platinum-rhodium thermo-



couple, magnetic contactor, Kanthal super elements, terminals, aluminum strips for terminal connections, and an element transformer. This series is available in box or tube-type units.

For further information circle No. 967 on literature request card, page 48-B.

Heat Exchanger

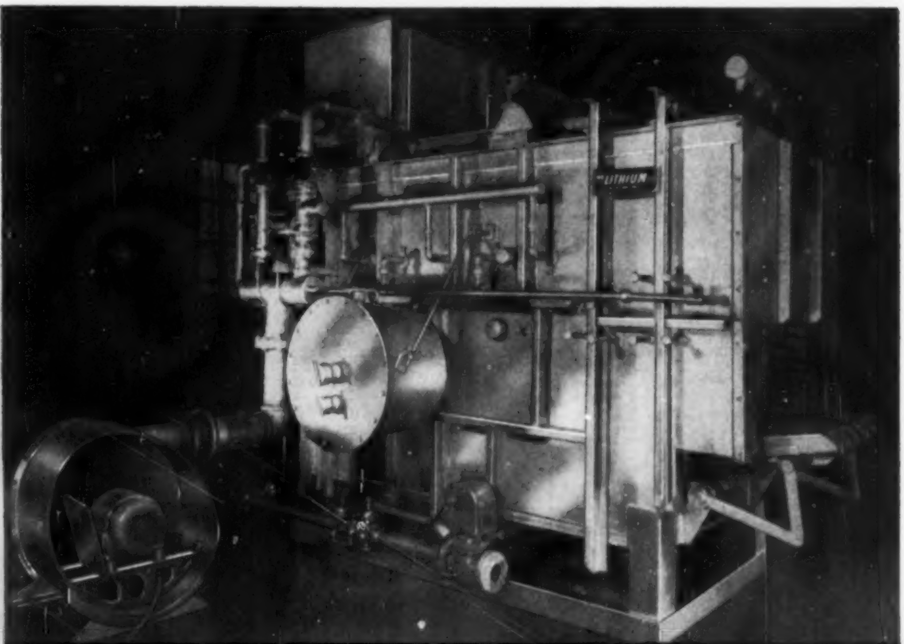
Niagara Blower Co. has announced a new model heat exchanger for liquid and gas cooling in industrial applications. Evaporation of a water spray over the cooling coils provides the cooling effect at the rate of about 1000 Btu. for each pound of water evaporated. The air stream, in which the heat is rejected, enters the unit near the top of one side, travels down-

SPENCER blowers

NOTE:
Furnace is used by The Lithium Co. to demonstrate quality heating processes. Upon request, furnace is placed in various plants to prove the processes.

FURNACE
HEARTH AREA...2' 6" x 6' 0"
DOOR HEIGHT...........10"
TEMP. RANGE...1200-2500°F
FUEL: Oil or Gas

BLOWER
TYPE: SPENCER CENTRIFUGAL TURBO-COMPRESSOR.



DIRECT FIRED RECUPERATIVE ATMOSPHERE SCALE-FREE HEATING FURNACE BY THE LITHIUM CO. . . EQUIPPED WITH SPENCER BLOWER.

. . . preferred on countless industrial heating applications

SPENCER blowers . . . competitively priced . . . are consistently preferred by leading manufacturers of industrial furnaces of all types because of:

Complete Dependability—Rugged castings, sheet steel fabrication, simple construction and wide clearances mean long, trouble-free performance . . . assured proper air delivery.

Engineering Cooperation—The vast experience and thorough technical knowledge of field representatives and staff engineers are always available to assist in developing or adapting a reliable Spencer blower to any new or unusual need.

Whatever *your* blower requirements, for incorporation on original equipment or for replacement, it will pay to check with SPENCER.

Request Bulletin 126-B containing complete information and specifications on Spencer Blowers.

SPENCER HARTFORD

The SPENCER TURBINE COMPANY
HARTFORD 6, CONNECTICUT

OTHER QUALITY SPENCER PRODUCTS

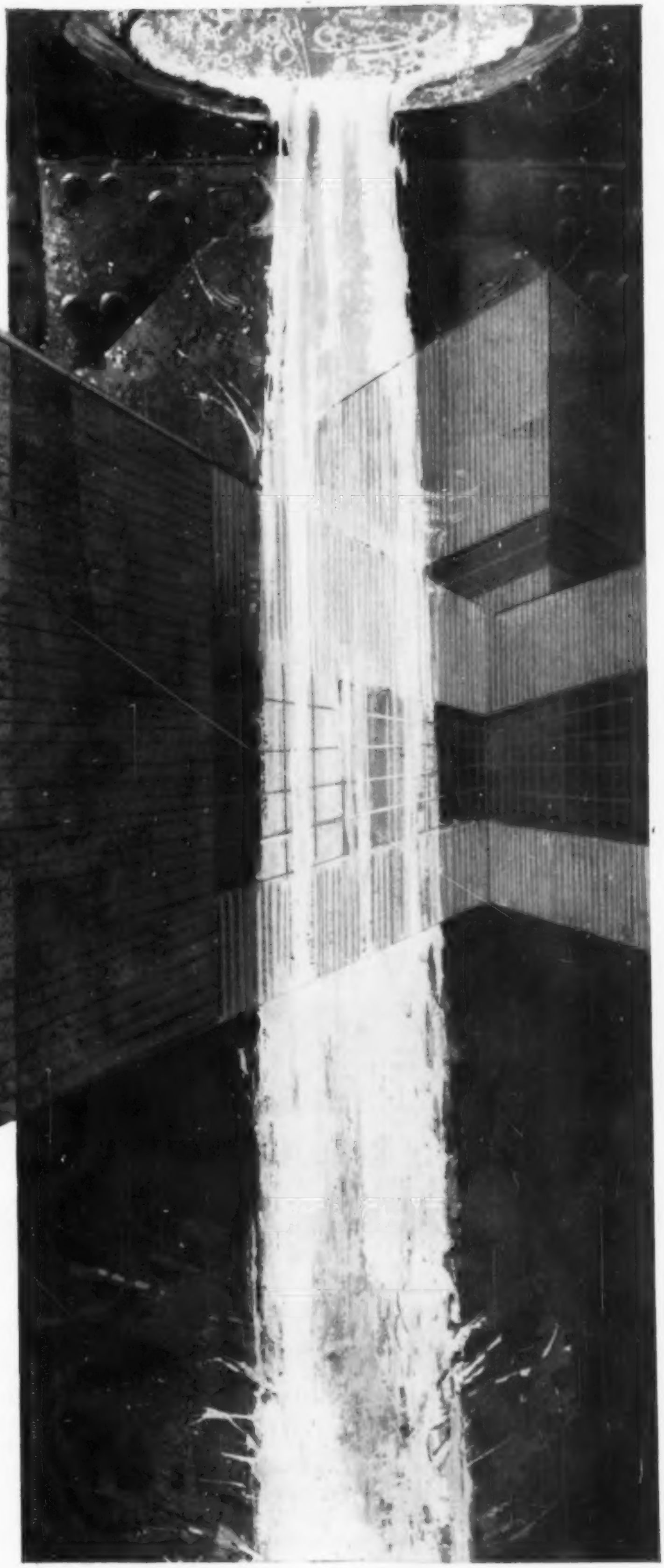
STATIONARY VACUUM SYSTEMS

PORTABLE VACUUM CLEANERS

PNEUMATIC CONVEYING SYSTEMS

one million pounds of vacuum induction melted alloys per month

That's the pouring capacity of our New Hartford plant! Expanded new facilities, together with precision melting and inspection practices, enable us to guarantee absolutely consistent quality from heat to heat. For information on ingot, billet, bar, sheet, strip and wire now available in commercial quantity, write
Metals Division,
Kelsey-Hayes Co.,
New Hartford, N. Y.



METALS DIVISION
KELSEY-HAYES

U DI MET®
ALLOYS

SOME ALLOYS COVERED BY U. S. PATENT #2809110

Ups cutting oil life 12 times with Gulfcut . . . more proof that

GULF MAKES THINGS

Not only the life of cutting oil, but the odor of it when rancid had once been a thorny problem in the Oil Tool Division of Reed Roller Bit Company, Houston, Texas, a major producer of oil well drilling tools.

Here's how they solved both problems with Gulfcut Heavy Duty Soluble Oil. Before they switched to Gulfcut, one department was changing cutting oils on the average of every two weeks. Reason: premature rancidity.

If the oil wasn't changed that often, the objectionable odor would become a personnel problem. Because it was changed that often, at least two man-hours were lost each time a machine was cleaned out. On top of this was the unnecessary cost of replacing oil that frequently.

The previous oil also tended to "clabber up" in the storage drums, especially in cold weather. This made it difficult to prepare the coolant charges. Reed solved all these problems with Gulfcut Heavy Duty Soluble Oil.

They reduced the frequency of cutting oil changes from an average of every 2 weeks to an average of every 6 months. Gulfcut Heavy Duty gave them over 12 times the service life! They had no more trouble with rancidity or solidification in storage.

What's more, in a water-oil ratio of 10-to-1, Gulfcut Heavy Duty Soluble Oil gives Reed's machinists the

Proof in production. These components for the new Reed Y tri-cone drilling bit were precision-bored in a turret drill cooled and lubricated with Gulfcut H.D. Soluble Oil. Boring operation at 550 sfpm. Carbide tool speed: 1,675 rpm. Cutting oil life in this operation: 6 months.

The Gulf man is there. Gulf Representative Jeff Bolling, right, talks to Reed shop superintendent A. R. Whiltsie about the merits of Gulfcut Heavy Duty Soluble Oil—which is used in a total of 21 lathes and drills in the Lugs and Bridges Department. All of the work involves alloy steels.

RUN BETTER!

constant work temperature and lubricity they need—for accurate sizing and desired surface finishes.

How about your operation? Gulfcut Heavy Duty Soluble Oil cuts machining cost through: longer cutting oil life, increased tool life, finer finishes, closer tolerances—and freedom from rancidity, foaming and solidification in storage.

Get the full efficiency-economy story on Gulfcut Heavy Duty Soluble Oil now. See how Gulf makes things run better, operation-wise and cost-wise. Call a Gulf Sales Engineer at your nearest Gulf office. Meanwhile mail coupon for new illustrated bulletin.

GULF OIL CORPORATION
Dept. DM, Gulf Building
Pittsburgh 30, Pa.

Send me illustrated bulletin on Gulfcut Heavy Duty Soluble Oil.

Name__________

Title__________

Company__________

Address__________

City__________ Zone____ State____

SP-9363

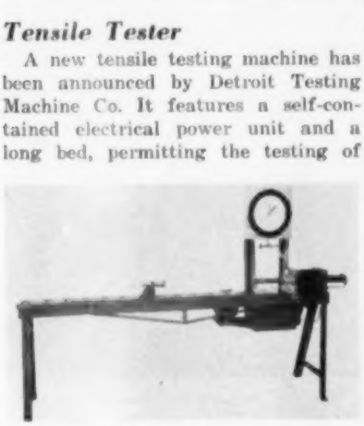
ward through the spray chamber and is drawn upward through the plenum and discharged by propeller fans. The fluid is cooled to a point close to the atmospheric wet bulb temperature. The control of temperature is automatic, governed by modulating the amount of air flow of fresh or re-

circulated air. The heat is removed at the rate of input. Special features include cleanable coils and "winter-summer" dampers that permit outdoor installation in severe climates with no danger of freezing damage. A range of sizes provides capacities up to 18,000,000 Btu. per hr.

For further information circle No. 968 on literature request card, page 48-B.

Tensile Tester

A new tensile testing machine has been announced by Detroit Testing Machine Co. It features a self-contained electrical power unit and a long bed, permitting the testing of



specimens up to 5 ft. long. The machine can be set to test for any load up to 10,000 lb., the maximum developed by the hydraulic cylinder.

For further information circle No. 969 on literature request card, page 48-B.

Cleaner

A new steel cleaner has been announced by the Northwest Chemical Co. Acid activating salt No. 1 is dustless, granular and free flowing. It can be used in conventional acid pickling operations and also serves as a chromium stripping bath at 200° F.

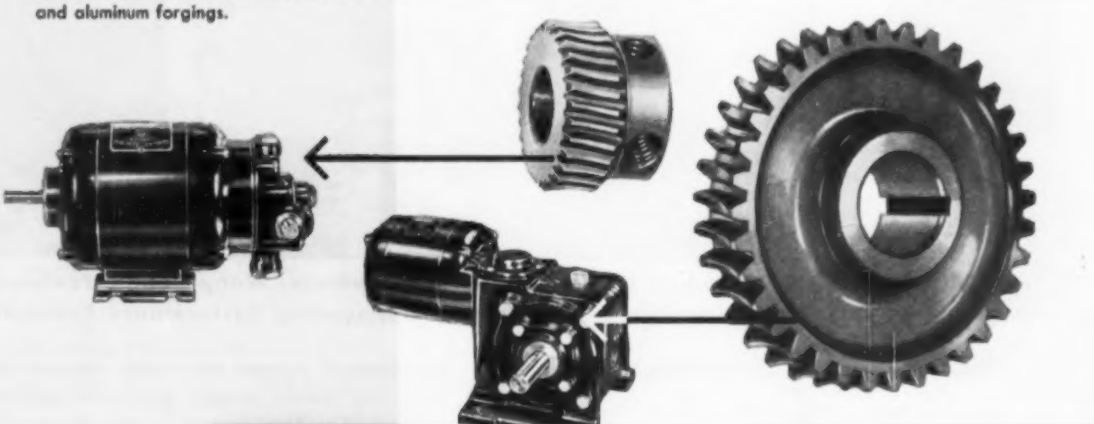
For further information circle No. 970 on literature request card, page 48-B.

MUELLER BRASS CO. forged gears improve dependability and performance of BODINE electric motors

For combined high shear strength and maximum wear life in their single and double reduction speed reducer motors, Bodine Electric Company of Chicago uses gears forged from Mueller Brass Co. 603 Alloy.

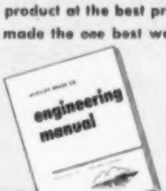
Bodine has specified Mueller Brass Co. forged gear blanks because of their consistently high quality . . . there is no porosity, foreign inclusions or defects typical of cast blanks. The hot working of the metal followed by heat treatment to the desired physical properties produces a refined grain structure to give uniform machining and wear in service. The forged blanks are consistent in size and held to close tolerances. Bodine has also found that the excellent machinability of the blanks in the hobbing operation increases overall hob life.

For forgings of high tensile strength, high density, minimum porosity, light weight, corrosion resistance, good machinability and low costs with little scrap loss, it pays to specify forgings from the Mueller Brass Co., the world's largest producer of brass, bronze and aluminum forgings.



only the man from Mueller Brass Co.

can offer unbiased advice on the "one best way" of producing your parts, because Mueller Brass Co. is the only fabricator in the country offering all these methods of production . . . assuring you the best product at the best price . . . made the one best way.



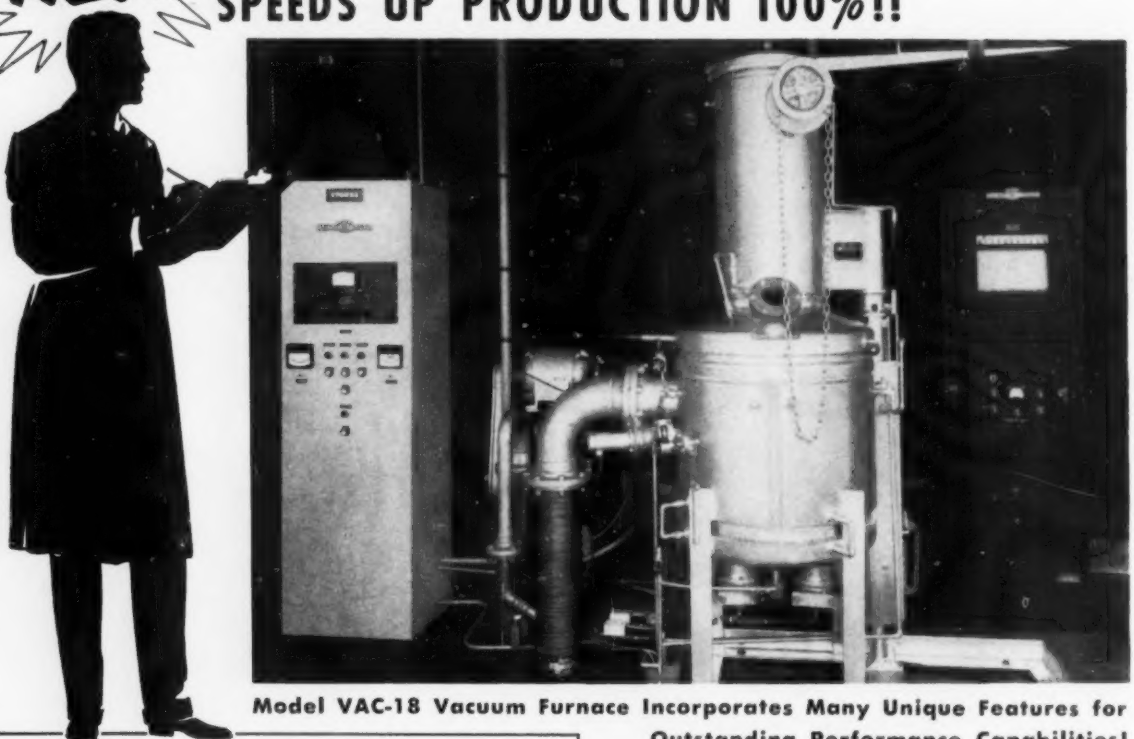
Write today for complete catalogs on any of these products.

Also producers of: Super Cutting Red Tip Brass Rod • Aluminum Extrusions Aluminum Sheet, Coil and Strip • Plastic Pipe and Fittings • Copper Tube and Solder Type Fittings •

MUELLER BRASS CO. PORT HURON 28, MICHIGAN

262

NEW HAYES *Vacuum* HEAT TREATING FURNACE SPEEDS UP PRODUCTION 100%!!



Model VAC-18 Vacuum Furnace Incorporates Many Unique Features for Outstanding Performance Capabilities!

MODEL VAC-18 FEATURES . . .

- ★ Temperature Range . . . from 700°F to **2150°F.**
- ★ Vacuum . . . set to operate at 0.1 micron, but will operate at different vacuums . . . as required.
- ★ Heating element of completely new design . . . operates at low voltage; allows heavier, self-supporting construction; eliminates need for refractory inside furnace.
- ★ Heating element operates on 3 phase current; arranged to come to uniform temperature; of simple construction, relatively inexpensive, and easily replaced; water-cooled leads and terminals.
- ★ "Hard-to-clean" baffles eliminated from inside unit . . . entire inner chamber of nickel-clad steel to speed up heating cycle
- ★ Hydraulic lift raises unit head (and integral cooling chamber) to facilitate work handling.
- ★ Water-cooled, fully jacketed chamber throughout . . . except for weld areas subjected to vacuum.
- ★ Saturable Reactor type power control maintains temperature of element . . . eliminates "on-off" control.

NOW OVER 3000°F

Metallurgical vacuum processing advances another great step toward meeting the severe performance demands of modern industry . . . with the introduction of the new Hayes Model VAC-18 Vacuum Heat Treating Furnace. Many unique features are incorporated in its design . . . to speed up the heating and cooling cycles . . . to facilitate work handling . . . and to improve process control and work-heating qualities.

Request complete information on these and other design features that make the Hayes Model VAC-18 Vacuum Furnace so completely new and outstanding in performance characteristics. Improve your product, increase output, and reduce unit costs . . . with GUARANTEED RESULTS! Let us show you what over fifty years experience in developing the well known line of CERTAIN CURTAIN electric furnaces and allied equipment can do for you. Write today!!

ELECTRIC CERTAIN ® CURTAIN FURNACES

C. I. HAYES, INC.

Established 1905

802 WELLINGTON AVE. • CRANSTON 10, R. I.

Free Literature

Please send complete data on the heat treating procedure checked here —

- ☐ Vacuum Heat Treating
- ☐ High Speed Hardening
- ☐ Tool Steel Hardening
- ☐ Carbo-Nitriding
- ☐ Tempering
- ☐ Bright Heat Treating
- ☐ Stainless Steel Heat Treating
- ☐ Sintering
- ☐ Copper Brazing and Soldering
- ☐ Lead Pot Hardening and Tempering
- ☐ Atmosphere Equipment
- ☐ Other . . . .

APPLICATION and EQUIPMENT

new literature

971. Abrasive Cleaning
Folder on Malleabrasive for airless blast cleaning equipment gives advantages, grades, equipment it can be used with and parts that can be cleaned. *Globe Steel Abrasive*

972. Acids
Bulletin on naphthenic acids for emulsions and corrosion inhibitors. General properties, specifications. *Sun Oil Co.*

973. Alloy Castings
New 8-page bulletin on ferrous alloy castings for the control of wear due to impact and abrasion. Application, production, physical properties. *American Manganese Steel Div.*

974. Alloy Steels
New 20-page booklet describes three high-strength, low-alloy steels. Mechanical characteristics and applications of each. *Kaiser Steel Corp.*

975. Aluminum Bronze
8-page booklet on aluminum bronze bearing material which is forgeable, corrosion resistant, lightweight. *Mueller Brass*

976. Aluminum Bronze Alloys
20-page booklet on chemistry, physical properties and uses of aluminum bronze alloys in rolled, extruded and cast forms. *Ampco*

977. Aluminum Die Castings
Bulletin on design and manufacture of aluminum die castings. *Hoover Co.*

978. Aluminum Extrusions
Folder lists alloys used, finishes, trade phraseology. *General Extrusions*

979. Aluminum Extrusions
Catalog of extrusion dies in stock. *Jarl Extrusions*

980. Aluminum Melting
Folder on electric furnaces for the aluminum alloy foundry. *Ajax Engineering*

981. Ammonia Dissociators
Data on Drever ammonia dissociators. Also nitriding, tempering, carburizing, and salt bath units. *W. H. Kay Co.*

982. Annealing Furnaces
8-page illustrated booklet on continuous annealing furnaces. Schematic diagrams, photographs, and actual production data. *Drever Co.*

983. Atmosphere Furnace
New 12-page Bulletin 850.20 on controlled atmosphere reciprocating hearth furnace for continuous hardening, light case carburizing, Ni-Carb ammonia-gas carburizing and other heat treating processes. *American Gas Furnace*

984. Atmosphere Furnace
12-page bulletin 1054 on electric furnaces with atmosphere control for hardening high speed steel. *Sentry*

985. Atmospheres
Bulletin 1-10 supplies technical information on inert gas generators and data on costs. *C. M. Kemp Mfg.*

986. Barrel Finishing
New 8-page booklet on barrel finishing compounds for deburring, burnishing, and descaling. Uses. Proper barrel technique. *Oakite*

987. Barrel Finishing
New Bulletin 255 describes barrel finishing equipment and accessories. Specifications, advantages. *Metal Finish, Inc.*

988. Belting
6-page Bulletin MF-600 on hinged steel belting. 6 inches to 6 feet in width, any length or capacity required. *May-Fran Engineering*

989. Brazing
Brazing News No. 79 tells of silver brazing's characteristics. Case histories. *Handy & Harman*

990. Calibrating System
New ABC booklet on force measuring system. *Morehouse Machine*

991. Carbides
New 24-page booklet on production of tungsten carbide products by both the hot and cold press method. *Metal Carbides*

992. Centrifugal Castings
Folder on advantages of centrifugally cast thermalloy. *Electro-Alloys*

993. Chromate Finishing
File on chromate conversion coatings for prevention of corrosion and paint-base treatment of nonferrous metals. *Allied Research Products*

994. Chromizing
4-page folder describes how to make iron powder components resistant to rust and wear. *Chromalloy*

995. Cleaning Costs
Booklet on new method for analyzing and comparing metal cleaning costs. Blank worksheet included. *DuPont*

996. Coated Metals
Bulletin on roll coating shows how it is done and includes samples. *Roll Coater*

997. Coating
New 12-page booklet 258 on Kanigen, chemically deposited nickel alloy coating. Heat treating curves, corrosion studies. *General American Transportation*

998. Coatings
4-page catalog on heat-proof protective coatings. Basic types, applications, methods of applying and temperature ranges. *Markal*

999. Compressors
New 12-page Bulletin 126-B on application of turbo compressors to oil and gas-fired equipment used in heat treating, agitation, cooling, drying. Performance curves, capacities. *Spencer Turbine*

1000. Conveyor Belts
Report on service life of woven wire conveyor belts operating at temperatures of 2050° F. *Cambridge Wire Cloth Co.*

1001. Copper Alloys
28-page specification index compares trade names and specifications of various agencies. Compositions of Anaconda alloys. *American Brass Co.*

1002. Copper Alloys
36-page catalog on phosphor bronzes, nickel silvers, beryllium copper, cupro-nickel. Chemical and physical data. Engineering tables. *Riverside-Alloy Metal*

1003. Corrosion-Proof Equipment
Bulletins on corrosion-proof tanks, ventilating equipment, agitators, baskets. *Heil Process Equipment*

1004. Creep Tester
Bulletin on new creep rupture tester designed for laboratory testing of small specimens. *Arcweld Mfg.*

1005. Cutting Oil
New folder describing nine types of cutting oils for varied applications. *Gulf Oil*

1006. Degreasers
Folder on vapor and solvent degreasers describes equipment and advantages. *Randall Mfg.*

1007. Degreasing
New Bulletin No. 70 on degreasing with trichlorethylene. Advantages and disadvantages. *Hooker Electrochemical*

1008. Electric Furnaces
Folder on electric furnaces with zone control, temperature indication, automatic control. *L & L Mfg. Co.*

1009. Electric Furnaces
8-page Bulletin 570 on heat treating, melting, metallurgical tube, research and sintering furnaces. Custom designs for special requirements. *Pereny*

1010. Electric Heating Unit
4-page folder describes controlled electric heating unit. Features, advantages, uses. *Herscott Co., Inc.*

1011. Electrochemicals
New 16-page booklet gives physical properties of 23 electrochemicals including silicon carbide, zirconium oxide and borides. *Norton Co.*

1012. Electropolisher
Theory and practice of electrolytic polishing of metallurgical samples. Describes electropolisher. Metal Digest, Vol. 1, No. 5. *Buehler, Ltd.*

1013. Environmental Unit
New 28-page booklet on testing chamber simulating atmospheric condition. Charts, technical data, application. *Webber Mfg. Co., Inc.*

1014. Extrusions
Bulletin on extruded seamless alloy and stainless steel tubing. Properties, shapes. *Metals Processing Div., Curtiss-Wright*

1015. Ferroalloys
New 4-page folder on Chromtemp exothermic ferrochromium. Advantages, selection of analysis and grades. *Electro Metallurgical Co.*

1016. Film Thickness Tester
Data sheets gives ranges, principle of operation of nondestructive thickness tester. *Unit Process Assemblies*

1017. Finishing
Data on automatic polishing, buffing, grinding, deburring and macro-finishing equipment. *Acme Mfg. Co.*

1018. Finishing
New 20-page booklet on tumbling media

ACHESON

dispersions digest

Reporting uses for

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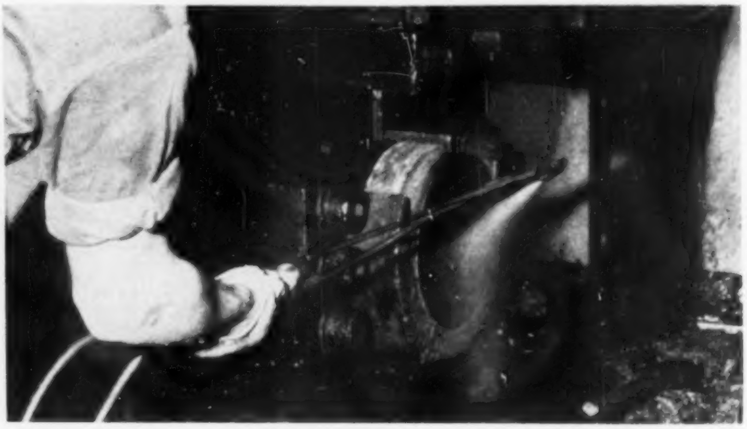
COLLOIDAL GRAPHITE, MOLY-SULFIDE, VERMICULITE, AND OTHER SOLIDS

WHY 'DAG' DISPERSIONS MEAN *PERFORMANCE* IN ALUMINUM EXTRUDING

The excellent lubricating properties of Acheson Colloidal Graphite, under conditions of extreme heat and pressure have been confirmed by leading extruders of aluminum, steel, copper, brass, lead and other metals. Water-base dispersions of colloidal graphite used in the following application histories have provided savings in material handling, reduced maintenance time and expense, prevented seizure, extended die life, and produced extrusions of more uniformly high quality. Any one of these benefits should make profitable reading for you.



For faster, more uniform application with less material consumption Aluminum Extrusions, Inc. finds 'Aquadag' their best die lubricant

A little 'Aquadag' goes a long way for Aluminum Extrusions, Inc., Charlotte, Michigan. This company, one of the leading independent extruders in the country, has found that by applying 'Aquadag' on die surfaces they have effected a 30% savings in their material handling. Formerly, they had used an oil-graphite mixture which required a dilution ratio of 16 lbs. of graphite to a 55 gallon drum of oil. It was too slowly applied by swab and too coarse to apply by spray with any degree of efficiency.

With 'Aquadag', Aluminum Extrusions has a lubricant that is finer in particle size, permits wider coverage, and provides greater "sprayability". These minute particles pass freely through the spray nozzle, eliminating the costly downtime formerly involved in cleaning clogged equipment. The tough, dry film 'Aquadag' forms upon the evaporation of its water carrier, doesn't smoke or react when applied to hot dies and metals. This improves working conditions as well as extends die life. Important also to both die surfaces as well as the finished extrusion, is the fact that this durable, low-friction film allows easier, more uniform metal flow.

Considered in relation to the over 12 million pounds of aluminum extruded yearly at this plant . . . 85% of it in fabricated form . . . *'Aquadag' has brought important production efficiencies and material economy* to Aluminum Extrusions, Inc. In many, similar instances where product quality and basic economy are demanded, Acheson colloidal dispersions have gained ready acceptance.

Exclusive Acheson processing techniques guarantee a consistently uniform top-quality product. If your problem is more effective lubrication under normally adverse conditions of extreme temperature, pressures, or abrasion, call in your Acheson Service Engineer.

Dies last three times longer with 'Aquadag', according to another prominent midwest extruder. Metal pickup on the extruding dies has been completely eliminated by the use of this Acheson dispersion, extending the effective use of the dies from 1000 to 3000 strokes. The evaporation of its water-base leaves a dry, adherent "graphoid" film on all lubricated surfaces, inhibiting the build-up of abrasive precipitates. At the same time, the unbroken, microscopically-thin film that 'Aquadag' provides, facilitates metal flow and reduces scoring to a negligible minimum. Application of the lubricant is by spraying a dilution of 1 part 'Aquadag' to 20 parts water, on the die surface before each "push" of the extrusion press.

A 'dag' graphite coating is also applied to the follow blocks on this company's 1400 ton horizontal extrusion presses. For purposes of even greater economy, 'Prodag' — semi-colloidal graphite in water — is used in this application. This effective parting agent prevents the flash, back-extruded from the billet skin, from locking the butt to the follow block. An Acheson dispersion is very possibly the answer to your lubricating troubles. For additional information, write for your free copy of Bulletin 426. Address Dept. MP-48.

Extended die life and extrusions with more perfect surface finish, are attributed to the use of 'Aquadag'.

ACHESON

ACHESON *Colloids Company*

PORT HURON, MICHIGAN

A division of Acheson Industries, Inc.

Also Acheson Industries (Europe) Ltd. and affiliates, London, England

50th

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for barrel finishing. Types of abrasive, applications, sizes and functions of barrels, job analysis. *Electro Minerals Div., Carborundum*

1019. Flow Meters
Bulletin 203 on flow meters for gas used in heat treating. *Waukee Eng'g.*

1020. Forging
Two bulletins on upset forging process, advantages of upset forging, quotation specifications. *Champion Rivet*

1021. Forging Materials
New 16-page booklet describes forging materials for aircraft and missile structural parts. 11 charts compare physical properties. *Steel Improvement & Forge*

1022. Forgings
Two bulletins on upset forging process, advantages of upset forging, quotation specifications. *Champion Rivet*

1023. Forgings
Series of articles on modern forging methods. *Hill Acme*

1024. Forgings
Bulletin on forge steelmaking, open die forging, machining, heat treating and finishing. *National Forge*

1025. Forgings
Folder on facilities for production of flat-die forged products. Electronic equipment used. *Smith-Armstrong*

1026. Forgings
12-page booklet on how forged weldless rings and flanges are made. Case histories. *Standard Steel Works Div., B-L-H*

1027. Formed Shapes
26-page catalog No. 1555 contains drawings and dimensions of more than 100 shapes. *Roll Formed Products Co.*

1028. Forming
New 88-page book on equipment and process of cold roll-forming. Wide sheets, narrow trim, tubular shapes, curving, coiling, tooling needed. *Yoder*

1029. Furnace
New 28-page Bulletin HD 646-R1 on vertical retort furnace for carburizing and nitriding. Construction and accessories. Discussion of carburizing and nitriding processes and procedures. *Hevi-Duty Electric*

1030. Furnace
New bulletin on basic principles of electric furnace design. Cutaway models of 8 furnaces. Cost factors. *Holcroft*

1031. Furnace Charging
12-page brochure on eight models of charging machines for heating and melting furnaces. *Salem-Brosius*

1032. Furnaces
12-page reprint on design, construction and application of chain belt conveyor furnaces. *Electric Furnace Co.*

1033. Furnaces
Bulletin on graphite tube furnaces for temperatures to 5000° F. Operating limitations, auxiliary and control equipment. *Harper Electric*

1034. Furnaces
Lists of surplus furnaces for sale. *Joe Martin Co.*

1035. Furnaces
New 12-page catalog on electric heat treating furnaces. Data on each of 57 models. Controls, instruments, elements and accessories. *Lucifer Furnaces, Inc.*

1036. Furnaces
New 26-page Bulletin S-1056 on steel heating equipment. Applications. *Selas*

1037. Furnaces
New Bulletin 200 describes complete setup for heat treatment of small tools, including draw furnace, quench tank and high temperature furnace. *Waltz Furnace*

1038. Gold Plating
8-page paper gives bath composition, equipment and operating conditions, and metallurgical characteristics of 24K gold plate on various base metals. *Sel-Rex*

1039. Graphite
New 12-page booklet on "The ABCs of Colloidal Dispersions". Answers to questions most frequently asked about colloids. *Acheson Colloids Co.*

1040. Hardness Numbers
Pocket-size table of Brinell hardness numbers. *Steel City Testing*

1041. Hardness Tester
New Bulletin F-1689-3 on Impressor portable hardness tester for aluminum, aluminum alloys and soft metals. *Barber-Colman Co.*

1042. Hardness Tester
20-page book on hardness testing by Rockwell method. *Clark Instrument*

1043. Hardness Tester
Catalog 505 on Frank hardness tester for Rockwell B and C, Brinell and Vickers hardness tests. *Opto-Metric Tools*

1044. Hardness Tester
Data on hardness testing scleroscope with equivalent Brinell and Rockwell C numbers. *Shore Instrument*

1045. Hardness Tester
4-page bulletin on tester for both superficial and regular hardness testing. *Torsion Balance Co.*

1046. Hardness Tester
Bulletin A-18 on Alpha Co. Brinell

Latest Scientific Equipment Aids Quality Control of Globe Ferroalloys

These views show some of the laboratory equipment at the Beverly, Ohio, plant.

The spectrograph, illustrated above, is used continually to control quality of Globe Ferroalloys.

The other view shows equipment, all under inert gas pressure, to insure accuracy. Modern electronic equipment is employed to determine alloying elements in Globe products.

Quality is a fetish in the production of Globe Ferroalloys . . . and much appreciated by users.

GLOBE
SILVERY IRON
FERROALLOYS

FERROSILICON

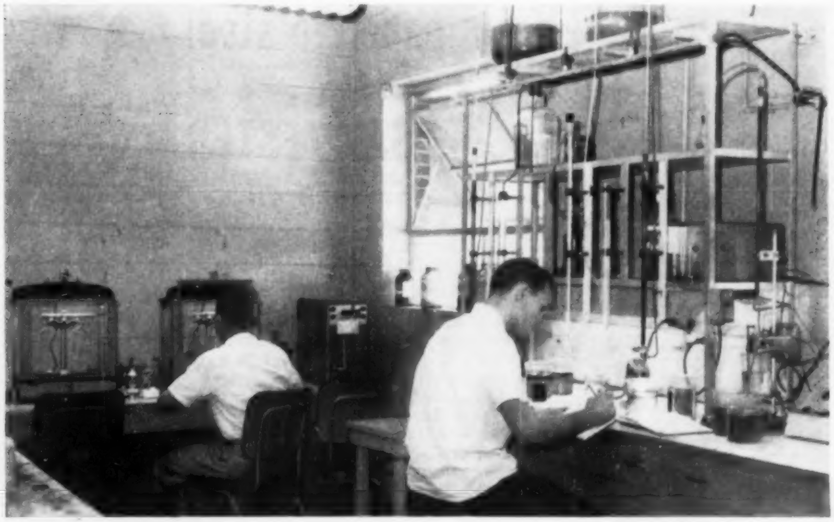
HIGH-CARBON FERROCHROME

LOW-CARBON FERROCHROME

LOW-CARBON FERROCHROME SILICON

SILICOMANGANESE

OTHER SPECIALTY ALLOYS



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CHICAGO • CINCINNATI • DETROIT • DULUTH • ERIE
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Serving Industry Since 1883

IRON ORE • PIG IRON • COAL • COKE • FERROALLOYS

PM

hardness testing machines. *Gries Industries*

1047. Hardness Testers
Folder on portable hardness testers for testing of various sizes, shapes and types of metal. *Newage Industries*

1048. Heat Exchangers
Bulletin 105 on heat exchangers, their pressure ratings and heat transfer ratings. *Thermal Research & Engineering Corp.*

1049. Heat Treating
Monthly bulletin on used heat treating and plating equipment available for immediate delivery. *Metal Treating Equip.*

1050. Heat Treating
Loose leaf data sheets on heat treating oils, salts, carburizing compounds. *Park Chemical*

1051. Heat Treating
Bulletin describes baskets, crates, trays, furnace parts for heat treating. *Stanwood*

1052. Heat Treating Belts
New 12-page catalog of conveyor belts and data for their design, application and selection. *Ashworth Bros.*

1053. Heat Treating Fixtures
New bulletin on formed and welded alloy heat treating furnace fabrications. *Alloy Engineering Co.*

1054. Heat Treating Fixtures
New brochure on complete line of heat treat baskets and custom designed heat treat fixtures. *Bix Co.*

1055. Heat Treating Fixtures
New 24-page Catalog 54 on light-weight processing and heat treating equipment. *Pressed Steel Co.*

1056. Heat Treating Fixtures
32-page Catalog G-10A lists process equipment, heavy welded fabrications, muffles, trays, fixtures for furnaces, heat treating equipment, pickling equipment. *Rolock*

1057. Heat Treating Fixtures
New 16-page Catalog M-7 on heat treating and corrosion resistant alloy fabrications. *Wiretex Mfg. Co.*

1058. Heat Treating Furnaces
New Bulletin No. HT-53 on heat treating furnaces. Construction, design, fuel used. *Carl-Mayer*

1059. Heat Treating Furnaces
Folder on industrial furnaces. Continuous designs. Insulation. *Pacific Industrial*

1060. Heat Treat Pots
Catalog on pressed steel pots for lead, salt, cyanide, oil tempering and metal melting. *Eclipse Industrial Combustion*

1061. Heaters
New Bulletin L-1244 on Chromalox stud heaters. How to use and table of sizes, ratings and prices. *Edwin L. Wiegand Co.*

1062. Heaters
Bulletin on immersion heaters for electroplating solutions. *Glo-Quartz*

1063. Heating Elements
12-page bulletin gives typical applications of silicon carbide heating elements. Hints on handling, unpacking, storage, installation, replacement. *Globar Div., Carborundum*

1064. High Speed Steels
New 8-page folder on high speed steels. Types, chemical analysis, heat treatment. *Marathon Specialty Steels, Inc.*

1065. Hot-Working Steels
New 10-page pamphlet on hot-working steels. Composition, machining and inspection, heat treatment. Properties, applications. *Marathon Specialty Steels*

1066. Indium
12-page booklet on standard-grade and high-purity indium and the fabricated forms supplied. *Consolidated Mining & Smelting Co.*

1067. Induction Brazing
Folder tells how tips of carbide may be brazed on tool shanks. *Ohio Crankshaft*

1068. Induction Heating
New brochure on low-frequency induction heating. Advantages and applications. *Electric Arc, Inc.*

1069. Induction Heating
12-page bulletin gives descriptions, technical data on various sizes. Water systems diagrammed, and standard accessory equipment. *High Frequency Heating Div., Lindberg Engineering*

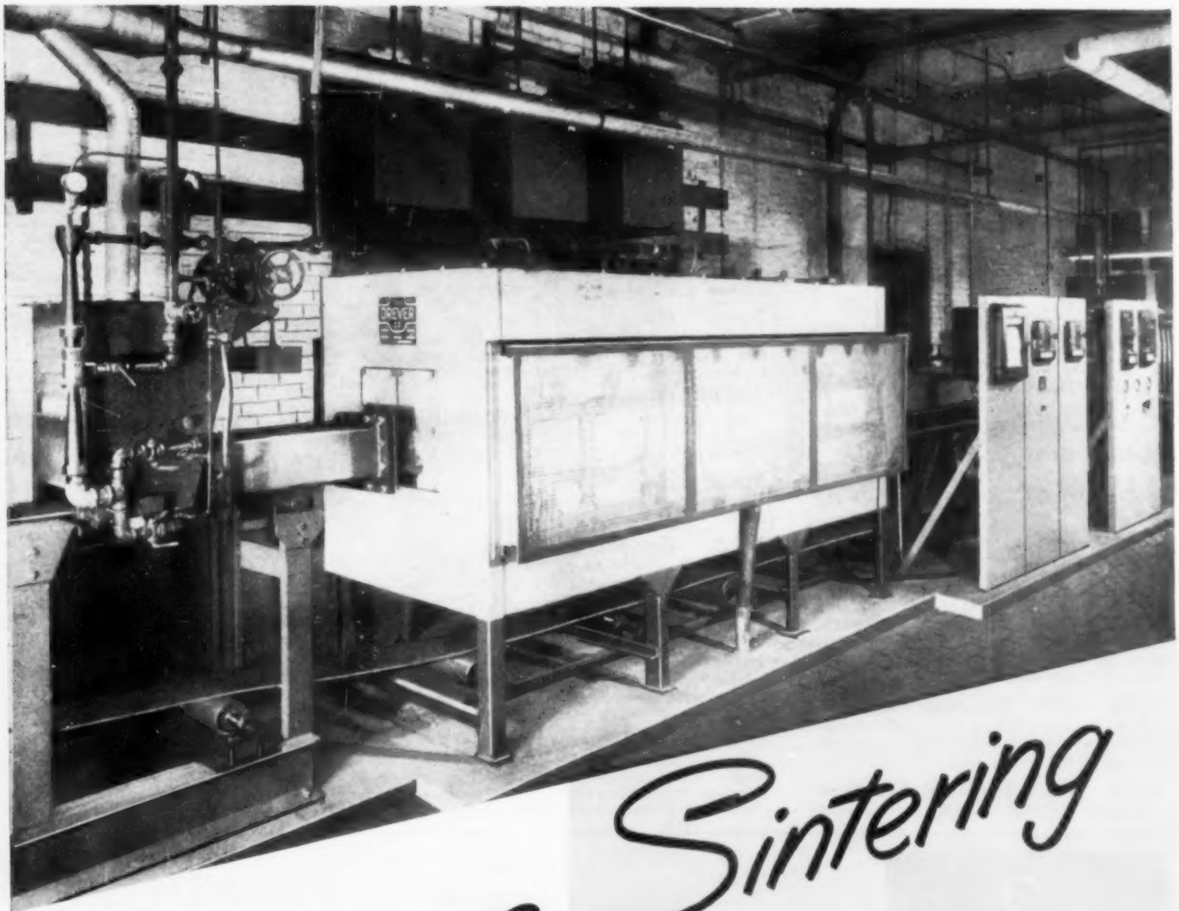
1070. Induction Heating
Brochure on induction heating furnace. Frequency chart. *Pittsburgh Induction Heating Co.*

1071. Induction Heating
Bulletin SK-4897 on inductor-type motor-generator sets for induction heating and melting. Electrical characteristics. *Star-Kimble Div., Safety Industries, Inc.*

1072. Inspection
Data on multi-frequency inspection of nonferrous and nonmagnetic metals. *Magnetic Analysis*

1073. Inspection
16-page catalog on illuminated Borescopes for industrial inspection of deep recessed areas. *National Electric Instrument*

1074. Investment Casting
August 1958, Vol. 1, No. 4, "Casting About with Misco," on factors which affect cost of investment castings. *Misco Precision Casting Co.*



Continuous Sintering

of

Brass, Bronze, Iron and Alloy Metal Powder Parts in one furnace

- The versatility of this furnace is of particular interest to the small producer.

Pictured is a 54-KW Belt Conveyor Furnace with Alloy Muffle.

Furnace is suitable for use with Dissociated Ammonia or any other controlled atmosphere.

Maximum operating temperature 2100°F. Complete automatic temperature control.

Burn-off Chamber can be added and is recommended for sintering brass.

Production 100 to 150 lbs/hour.

DREVER COMPANY

RED LION RD. AND PHILMONT AVE.
BETHAYRES, PA.

1075. Iron Powders
New 48-page booklet on three types of iron powders. Applications, chemical composition, physical properties. 27 pages of graphs. *Metal Powder Div., Republic Steel*

1076. Laboratory Equipment
16-page Laboratory Spotlight lists optical equipment and instruments for metallurgical laboratory. Cut-off machines, polishing tables, etc. *Harshaw Scientific*

1077. Laboratory Equipment
12-page catalog on high-frequency induction combustion units and accessories for carbon, sulphur and hydrogen analysis. *Lindberg Engineering*

1078. Laboratory Equipment
Bulletin on high-purity graphite powder, funnels, crucibles, boats. *United Carbon Products*

1079. Laboratory Furnace
Data on nonmetallic resistor furnaces for research, testing or small-scale production. *Harrop Electric Furnace*

1080. Laboratory Furnace
Bulletin RT-10 on 25 lb. per hr. laboratory metal treating unit for carburizing, hardening, carbonitriding, brazing, carbon restoration. *Ipsen*

1081. Laboratory Furnaces
Folder describes and illustrates tubular furnace for use in tensile testing, and control panels. *Marshall Products*

1082. Leaded Steels
16-page booklet on basic characteristics, mechanical properties and workability of leaded steels. Case histories. *Copperweld Steel Co.*

1083. Low-Alloy Steel
60-page book on high-strength low-alloy steel. Properties, fabrication and uses. *U. S. Steel*

1084. Low Temperature Treatment
Data sheets and case histories of stability achieved in metals by chilling at −130 to −150° F. Effect on further processing. *Harris Refrigeration*

1085. Lubricant
New 8-page Bulletin 304 on use of molybdenum disulfide lubricant in cold forming, cold heading and other applications. Case histories. *Alpha Molykote*

1086. Lubricants
8-page booklet on colloidal greases, forging compounds, hydraulic concentrate and others. *Grafo Colloids*

1087. Magnesium
53-page book on wrought forms of magnesium. Includes 44 tables. *White Metal Rolling & Stamping Corp.*

1088. Metal Analysis
New brochure on production X-ray Quantometer. Principle, design, applications. *Applied Research Lab.*

1089. Metal Ceramics
New 12-page booklet gives properties and typical applications of three metal-ceramics. Their compositions, design considerations, finishing. *Haynes Stellite*

1090. Metal Powders
Properties of Plast/Iron with and without copper. *Plastic Metals Div.*

1091. Metal Sorting
Data on nondestructive sorting tool for raw, semi-finished or finished parts. *J. W. Dice*

1092. Metals Processing
8-page brochure on equipment and facilities for precision cold rolling, forging, vacuum and air melting. *Precision Metals Div., Hamilton Watch*

(Continued on page 48-A)

The Legendary Firebird, the Phoenix, rose young and strong again and again from flames . . . This is the new Norton Firebird— symbol for the exciting new fused materials made in Norton's electric furnaces.

ZIRCONIUM: gift of the Firebird

Like the legendary Phoenix, Norton electrochemicals are born in raging flames — armed with power to perform new wonders. Among these modern materials are zirconium compounds formed at terrific heat in Norton electric furnaces.

Today, zirconium compounds are among the most interesting developments of modern electrochemistry. Norton now supplies these to industry as oxides, carbides, borides and nitrides, as well as calcium zirconate.

While the complete extent of zirconium's usefulness has not yet been fully explored, the Norton compounds of this element offer many new applicational possibilities — as source materials, metallurgical additives, cermet components, electrical conductors and refractories.

So do many other products of Norton electrochemical engineering, one or more of which may be vital aids to your own processing.

FREE CATALOG. For a complete list, with detailed descriptions, write for the new booklet *Norton Electrochemicals . . . Gifts of the Firebird* to NORTON COMPANY, Electro-Chemical Division, 810 New Bond Street, Worcester 6, Massachusetts.

NORTON

ELECTROCHEMICALS

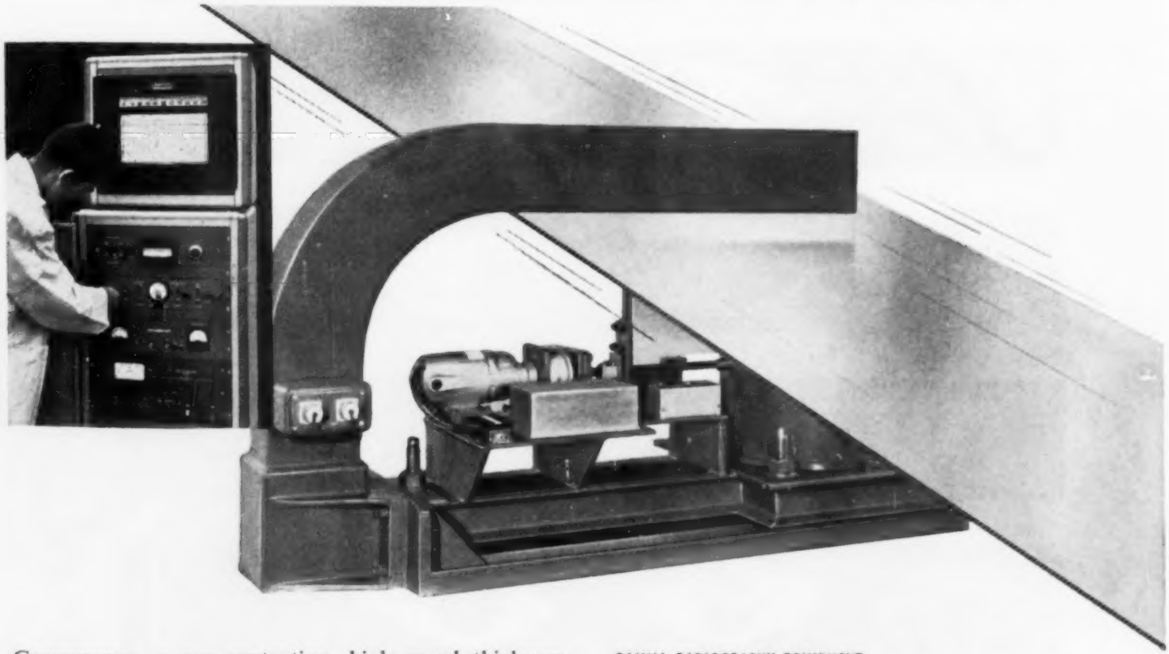
Gifts of the Firebird: compounds of silicon • zirconium • boron • aluminum • magnesium • titanium • chromium . . . including many borides • carbides • nitrides • oxides

MAKING BETTER PRODUCTS . . . TO MAKE YOUR PRODUCTS BETTER

Announcing

NUCLEAR SYSTEMS' GAMMASCAN THICKNESS GAGE

Precise, high-speed measurements . . . from light gage metal to more than a foot of steel



Gammascan, a non-contacting, high speed thickness gage, is capable of providing continuous measurement of deviations in a wide range of materials and thicknesses.

By utilizing gamma radiation from a shielded Cobalt 60 source and a special scintillation detection system, Gammascan indicates thickness deviations within milliseconds—deviations as small as .001" of steel. It can be linked with a chart recorder as well as servo-mechanisms for positive production control. One calibration allows 24 hours of continuous operation.

Gammascan is just one product of the constant research and development going on at Nuclear Systems. Also offered are . . .

GAMMA IRRADIATION FACILITIES
Cobalt 60 sources and lead-shielded facilities for conducting radiation research in your own laboratory.

GAMMA RADIOGRAPHY EQUIPMENT
Gamma sources and machines for radiographic inspection of weldments, castings, and solid fuel propellants.

RADIOACTIVE SOURCES
Isotope source material and encapsulation facilities available for special source requirements.

COBALT 60 TELETHERAPY SOURCES
Medical sources in standard international teletherapy capsules provided for commercial or custom installations.

CONTRACT RESEARCH AND CONSULTING
in fields related to our product line . . . including nondestructive testing in such diverse areas as gamma probing of reactor shielding and missile solid fuel propellants.

For full particulars about the new Gammascan, or any of our other products or services, contact our nearest sales office.

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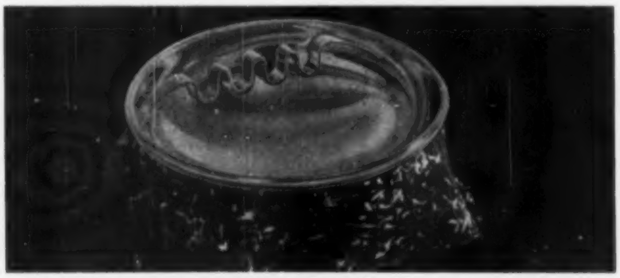
Sales Offices: PHILADELPHIA 32, PA. • CHICAGO, ILL. • SAN FRANCISCO, CAL. • INGLEWOOD, CAL.

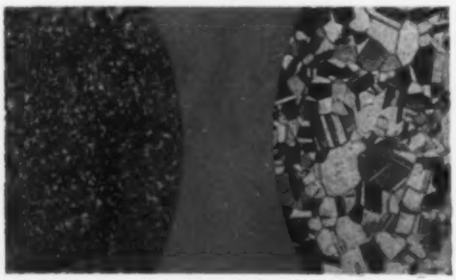
NEW BRASS SPEEDS FINISHING operations for Park Sherman Co.—Formbrite, Superfine-Grain Drawing Brass by Anaconda, reduces polishing time—cuts cost up to 50%—gives clean, easy formability.

TO THE PARK SHERMAN CO., Springfield, Ill., finishing operations are important in giving its line of fine brassware sales appeal—are also weighty cost factors. Switching from ordinary drawing brass to Formbrite, Park Sherman boosted production on the tray of this "Merry-Go-Round" Bar—25% in the cutting operation—42% in finish buff.

THE COVER of this Park Sherman Silent Butler is now made of Formbrite, Anaconda's Superfine-Grain Drawing Brass. Polishing operations in preparation for chromium plating are 50% faster than with ordinary drawing brass.



PRODUCTION INCREASED 47% in finishing operations on this Park Sherman Sta-Put ashtray after the shift to Formbrite. Products shown are only three of many Park Sherman products now made of Formbrite.



THE SECRET of Formbrite's superior polishing characteristics is its superfine-grain. Micrographs (75X): left, Formbrite; right, ordinary drawing brass.

Wherever finishing is an important cost factor in formed or drawn products, Formbrite in sheet and strip is designed to save you money. In brass wire alloys for cold-heading and upsetting, it gives a stronger, springier, more abrasion-resistant product. For more detailed information, write for Publication B-39. Address: The American Brass Company, Waterbury 20, Conn. In Canada: Anaconda American Brass Ltd., New Toronto, Ont.

FORMBRITE®

SUPERFINE-GRAIN DRAWING BRASS

a product of

ANACONDA®

Made by The American Brass Company

MEL-TROL®

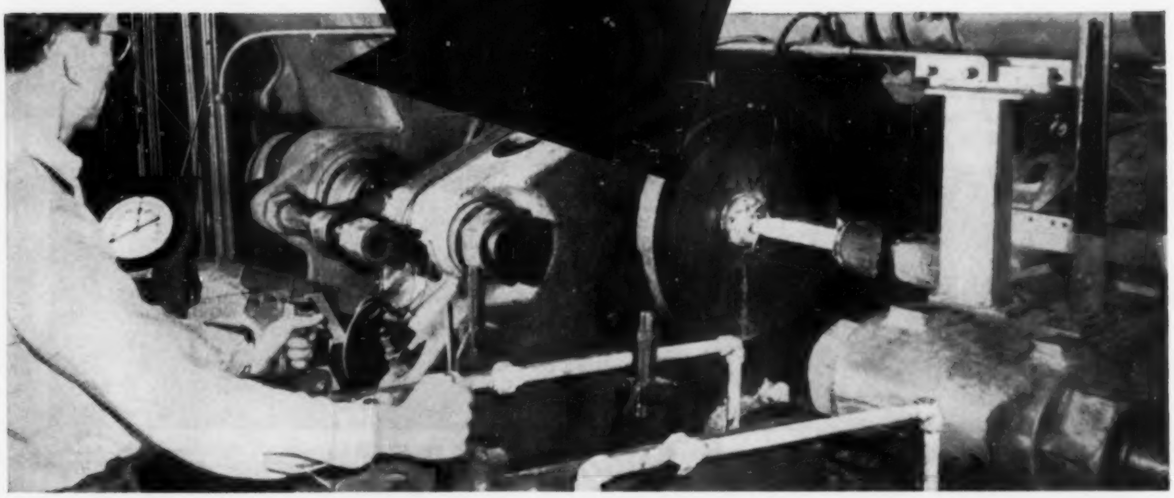
at work

An extrusion die's performance depends on strength and toughness at its center. And the center can only have as much strength and toughness as the ingot from which it came.

That's why MEL-TROL hot work die steels, *Carpenter* No. 345 and No. 883, for instance, invariably outperform other die steels used in aluminum extrusion.

MEL-TROL is a system combining the newest and best quality controls and an exclusive new, patented ingot mold. It produces ingots that are of consistently greater uniformity and better quality through the core than any die steels yet produced by conventional methods.

Ask for *Carpenter* No. 345 and No. 883. Your *Carpenter* representative will help you select the one best for your needs from large local stocks. Place your order today.



Carpenter STEEL

The Carpenter Steel Company, Main Office and Mills, Reading, Pa.
Alloy Tube Division, Union, N. J.
Carpenter Steel of New England, Inc., Bridgeport, Conn.
Webb Wire Division, New Brunswick, N. J.

(Continued from page 43)

1093. Metallizing
Folder on types, sizes and prices of metallizing wires. *Spra Rod Corp.*

1094. Metallograph
12-page bulletin on desk-type and research metallographs. Accessories, illuminating systems, specifications. *American Optical*

1095. Microhardness Tester
Bulletin describes the Kentron microhardness tester. *Torsion Balance*

1096. Microscopes
22-page catalog describes microscopes featuring ball bearings and rollers throughout the focusing system and a low-position fine adjustment. *Bausch & Lomb*

1097. Microscopes
Catalog on metallograph and several models of microscopes. *United Scientific*

1098. Nondestructive Testing
8-page bulletin on equipment for nondestructive testing of bars, rods, tubing. *Magnetic Analysis*

1099. Nonferrous Wire
Folder gives wire gage and footage chart and data on beryllium copper, phosphor bronze, nickel, silver, brass and aluminum wire. *Little Falls Alloys*

1100. Oil Quenching
8-page brochure tells in detail how carbon steel often can replace alloy steel when additive is used in the quenching oil. *Aldridge Industrial Oils*

1101. Optics
Catalog on optics for industry. Comparators, lenses, prisms, microscopes, magnifiers. *Edmund Scientific*

1102. Ovens
New folder, Form 4999 on ovens for baking, drying and heating. Continuous conveyor-line or complete portable ovens. Application data. *Lighting Div., Safety Industries, Inc.*

1103. Ovens
16-page Bulletin 157 on ovens for baking, drying, curing and heat treating. Batch and conveyor types. Air recirculating and heating systems. *Young Bros.*

1104. Perforated Metals
4-page folder gives ordering specifications and patterns. *Wickwire Spencer Steel Div., Colorado Fuel and Iron Corp.*

1105. Pickling Baskets
Data on baskets for degreasing, pickling, anodizing and plating. *Jelliff*

1106. Plating
8-page brochure on test equipment for plating baths. Controls, anodes, cathodes, agitators, rectifiers. *R. O. Hull*

1107. Portable Pyrometer
New bulletin on potentiometer type portable pyrometer indicator. Construction, range, operation. *Thermo Electric*

1108. Potentiometers
4-page Bulletin 1271 on small self-balancing electronic potentiometers and bridges. *Bristol Co.*

1109. Precision Casting
8-page bulletin on investment castings of various ferrous and nonferrous alloys. *Engineered Precision Casting*

1110. Pyrometer
New 12-page Bulletin No. 4257 on contact pyrometer for surface temperatures. Describes and illustrates instrument and it uses. *Illinois Testing Lab.*

1111. Pyrometer
Catalog No. 100 on radiation pyrometers with ranges from 1000 to 3400° F. *Pyrometer Instrument Co.*

1112. Radiography
Reprint from Canadian Metalworking describes powerful gamma radiography machines which can be used to radiograph sections up to 10 in. *Budd Co.*

1113. Radiography
16-page booklet on materials and accessories for industrial radiography. Guide to selection of film. Recommended development techniques. *Eastman Kodak, X-Ray Div.*

1114. Recirculating Furnace
New Bulletin No. 13-A on continuous-type recirculating furnace shows design of furnace, its operation and advantages. *Industrial Heating Equipment Co.*

1115. Refractory Metals
12-page bulletin on tungsten, molybdenum, zirconium, titanium and tantalum for alloying. Analyses, properties, grades. *Metals and Residues*

1116. Residual Stresses
32-page pocket-size booklet on residual stresses in cold finished steel bars and their effect on manufactured parts. *La-Salle Steel*

1117. Rhodium Plating
Data on rhodium sulphate and on limited time tests of this rhodium concentrate. *Technic*

1118. Rivets
48-page catalog of rivets gives manufactured shapes and sizes, tables of approximate weights, working temperature chart. *Champion Rivet*

1119. Rolling Mill
New brochure on rolling precision precious metal electrical contact tape. Equipment used. *Fenn Mfg.*

1120. Rust Prevention
Nine bulletins in one folder on rust prevention. Theory of corrosion. *Production Specialties*

1121. Salt Bath Furnaces
Data on salt bath furnaces for batch and conveyorized work. *Upton*

1122. Salt Baths
New 76-page Catalog 117 on salt bath equipment and procedures describes new ceramic tile pot furnaces with removable submerged electrodes. Technical data, applications. *Ajax Electric*

1123. Sand Systems
Bulletin No. SL-3 shows layout of system and controls. *Harry W. Dietert*

1124. Saws
Catalog C-55 describes 35 models of metal-cutting saws. *Armstrong-Blum*

1125. Shear
Bulletin on bar and billet shear for rounds, squares, flats, billets and structurals. Hot or cold operation. *Hill-Acme*

1126. Shell Molding
New 4-page Data Sheet SF-1128 on silicones for the shell molding process describes three different products. *Silicones Div., Union Carbide*

1127. Silver Brazing
43-page manual on all aspects of silver brazing applications and problems. *American Platinum & Silver Div.*

1128. Slitting
New 48-page Bulletin 571 on rotary slitting knives, trimming knives, pipe and tube cut-off knives and others. Standard and special types of high speed steel and carbide tipped milling cutters. *Cowles Tool Co.*

1129. Spectrograph
New 8-page catalog on Spec-Lab. Performance and applications of three models. *Jarrell-Ash*

1130. Spectrographic Sources
4-page bulletin 35A on spectrographic source unit gives data on three units available. *Baird Atomic*

1131. Spring Steels
New 8-page bulletin on tempered spring steels. Six physical property charts. *Wallace Barnes Steel Div.*

1132. Stainless Fastenings
20-page catalog of stainless steel cap screws, nuts, washers, machine screws, sheet metal screws, set screws, pipe fittings and specialties. *Star Stainless Screw*

1133. Stainless Steel
20-page catalog on corrosion characteristics of 20% chromium—29% nickel stainless steels, with and without columbium. *Carpenter Steel*

1134. Stainless Steel
New data sheets covering 17 types of stainless steels. Chemical composition, applications, processing, physical and mechanical properties, machining, forming, welding. *Jones & Laughlin*

1135. Stainless Steel
32-page book on corrosion resistance of stainless steels. 18 tables on tests in acid, neutral and alkaline solutions. *International Nickel*

1136. Stainless Steels
10-page booklet contains charts, graphs, data on properties of chromium-nickel manganese steels. *Allegheny Ludlum*

1137. Steel
Bulletin on Yoloy "S" steel. Properties, welding, chemical analysis, corrosion resistance, strength. *Youngstown Sheet & Tube*

1138. Steel Treating
Bulletin on flame hardening, induction hardening, carbonitriding, nitriding, liquid carburizing, Chapmanizing. *Lakeside Steel Improvement*

1139. Sub-Zero Treatment
New 10-page bulletin on industrial chilling equipment for shrinking, testing and treating of metals. *Cincinnati Sub-Zero Products*

1140. Superalloys
New 42-page booklet on superalloys for pipe and tubing. Corrosion resistance, mechanical properties, applications. *Damascus Tube Co.*

1141. Temperature Measuring
Bulletins on Tempilstiks and Tempilaq describe products and tell how to use them. *Tempil° Corp.*

1142. Testing
Folder on laboratory facilities for handling research problems involving microscopy, X-ray. *Ernest F. Fullam, Inc.*

1143. Testing
10-page article, Bulletin M-2, on testing copper single crystals. *Instron Eng'g.*

1144. Test Specimens
Data on machine for cutting test specimens to ASTM specifications. *Sieburg*

1145. Thermocouple Parts
New 36-page Catalog 1885 on thermocouple assemblies. Assembly instructions, specifications, applications. Pressure and temperature ranges. *Conax Corp.*

1146. Thermocouple Wire
New Bulletin No. 1200-4 on thermocouple wire with ceramic alloy insulation. Sizes of wire and types of sheathing. *Claud S. Gordon*

1147. Thermocouples
New Bulletin P1281 describes Armorox thermocouples. Available types, materials, sizes, and thermocouple curves. Applications. *Bristol Co.*

1148. Thermometers
New 8-page Bulletin 13E on stainless steel thermometers. Specifications and prices on angle form, straight form and special-purpose. *W. C. Dillon*

1149. Thickness Gage
Folder on pocket-size gage. How to use it. *Ferro Corp.*

1150. Tin
20-page bulletin on importance of tin to the American industry. Applications in aircraft, chemical, container, electrical, electronic equipment. *Malayan Tin Bureau*

1151. Titanium
8-page booklet on corrosion resistance of titanium. Table of ratings of titanium compared with stainless and aluminum in various mediums. *Mallory-Sharon Metals*

1152. Tool and Die Steels
26-page book on six oil and air hardening steels for high-production tools and dies. Uses. *Bethlehem*

1153. Tool Steel Failures
124-page book, "Tool Steel Trouble Shooter," analyzes 107 tool failures and assigns causes as among tool design faults, tool steel faults, improper heat treatment, mechanical and operational factors. *Bethlehem Steel*

1154. Torsion Testers
New 8-page Bulletin RT-10-54 gives details of construction, pendulum-type testers, torsion testers for wire. *Riehle*

1155. Tubing
New 60-page handbook on cold drawn butt welded mechanical steel tubing. 75 photos and drawings explain production, finishing and inspection. Applications. *Pittsburgh Tube Co.*

1156. Tubing
New 12-page bulletin on precision tubing for industry. Sizes, alloys, tempers, tolerances. *Precision Tube Co.*

1157. Tubing
New 6-page Data Memorandum No. 20 on tubing for atomic power. Uses, characteristics and size limits, applications. *Superior Tube Co.*

1158. Tukon Tester
New 12-page Bulletin DH-328 on Tukon micro and macrohardness testers. *Wilson Mechanical Instr.*

1159. Tungsten Alloy
Bulletin on properties and uses of 90% tungsten alloy, balance nickel and copper. *Firth Sterling, Inc.*

1160. Vacuum Crucibles
Bulletin on copper crucibles fabricated, machined and vacuum tested to customers' specifications. *Zak Machine Works*

1161. Vacuum Melting
8-page bulletin on production and testing equipment for vacuum melting. Advantage. *Utica Metals Div.*

1162. Valves
New 24-page Catalog V-58 on magnetic and motorized valves for use with air, water, gas, steam, oil and refrigerants. Dimensional drawings. *Mercoid*

1163. Vanadium in Steel
189-page book on properties of ferrous alloys containing vanadium and their applications. *Vanadium Corp.*

1164. Ultrasonics
Data sheets on high-power ultrasonic generators for mass production and ultrasonic scrubber. *Acoustica Associates*

1165. Ultrasonics
Data sheet on gages for thickness measurement, coating measurement, inspection. *Branson Instruments*

1166. Welded Assemblies
New 20-page catalog of welded precision assemblies, rings and bands. Metals used. *American Welding & Mfg. Co.*

1167. Welder
New brochure on semi-automatic welder. Construction features. Applications in representative industries. *Wall Colmonoy*

1168. Welding Electrodes
40-page Catalog No. 57A on mild steel, iron powder, stainless steel, hard surfacing and other electrodes. Properties, AWS classifications. *Champion Rivet*

1169. Welding Electrodes
New 88-page pocket-size booklet describes characteristics, coating, sizes of various electrodes. Standard designations. *Harnischfeger*

1170. X-Ray
12-page bulletin on gamma radiography tells how to select the source, equipment, techniques and fundamentals of gamma radiation. *Picker X-Ray*

1171. Zinc Coating
8-page booklet on zinc-coated steel sheets. Fabrication, uses, advantages in heating, ventilating and air conditioning. *Weirton Steel*

November, 1958

940	962	984	1006	1028	1050	1072	1094	1116	1138	1160
941	963	985	1007	1029	1051	1073	1095	1117	1139	1161
942	964	986	1008	1030	1052	1074	1096	1118	1140	1162
943	965	987	1009	1031	1053	1075	1097	1119	1141	1163
944	966	988	1010	1032	1054	1076	1098	1120	1142	1164
945	967	989	1011	1033	1055	1077	1099	1121	1143	1165
946	968	990	1012	1034	1056	1078	1100	1122	1144	1166
947	969	991	1013	1035	1057	1079	1101	1123	1145	1167
948	970	992	1014	1036	1058	1080	1102	1124	1146	1168
949	971	993	1015	1037	1059	1081	1103	1125	1147	1169
950	972	994	1016	1038	1060	1082	1104	1126	1148	1170
951	973	995	1017	1039	1061	1083	1105	1127	1149	1171
952	974	996	1018	1040	1062	1084	1106	1128	1150	
953	975	997	1019	1041	1063	1085	1107	1129	1151	
954	976	998	1020	1042	1064	1086	1108	1130	1152	
955	977	999	1021	1043	1065	1087	1109	1131	1153	
956	978	1000	1022	1044	1066	1088	1110	1132	1154	
957	979	1001	1023	1045	1067	1089	1111	1133	1155	
958	980	1002	1024	1046	1068	1090	1112	1134	1156	
959	981	1003	1025	1047	1069	1091	1113	1135	1157	
960	982	1004	1026	1048	1070	1092	1114	1136	1158	
961	983	1005	1027	1049	1071	1093	1115	1137	1159	

METAL PROGRESS,

7301 Euclid Avenue, Cleveland 3, Ohio

Please have literature circled at the left sent to me.

Name ____________________

Title ____________________

Company ____________________

Address ____________________

City and State ____________________

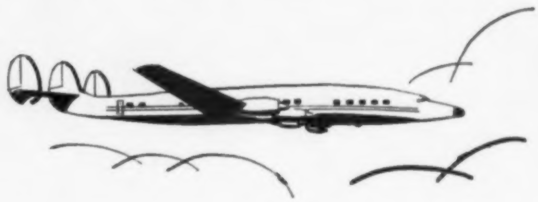
Postcard must be mailed prior to Feb. 1, 1959.
Students should write direct to manufacturers.

B-1 Flux is particularly effective in removing refractory oxides such as those formed in stainless steels.

Operator fits preformed ring of BRAZE 541 prior to fluxing. This is a hose and tube assembly for an oil line.

Here operator applies gas-air torch, hand-feeding BRAZE 541 to joint.

Oil-bearing unit under induction heating.



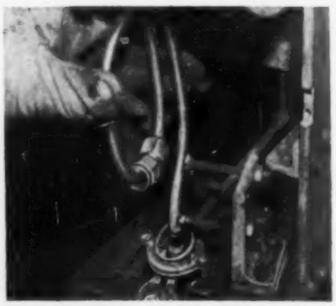
Here's How Stainless Steel Fuel Systems Benefit From

HANDY & HARMAN SILVER BRAZING

Tube Processing Corporation, Indianapolis, Indiana, makes aircraft and missile fuel systems and, if anything has to be more failure-proof than a fuel line assembly in an airplane, you name it. The units shown here are made of 410 stainless steel tube and 321 stainless steel fittings; when they're joined, they must be joined permanently. Exhaustive tests, including X-ray, pass on each assembly before final acceptance.

To meet all requirements: strength, ductility, liquid and airtightness, production speed and economy, Tube Processing uses Handy & Harman's special alloy BRAZE 541 (formerly Alloy 4772) and HANDY B-1 FLUX.

Developed strictly for brazing stainless, BRAZE 541 is one of many Handy & Harman brazing alloys—both standard and special—made to do a specific job and do it better than any other metal-joining method.



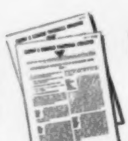
Operator placing oil line (of another type) in induction heating ring.

Name your product and the metals it's made of, the chances are very good indeed that one of Handy & Harman's silver brazing alloys can join it better than the method you now employ. Better from every aspect: economy, speed, strength, conductivity, labor savings. Put your product in these pictures for the same benefits.

An exclusive additional benefit is Handy & Harman's application Engineering Service. This is a service that exists to show you how these benefits can best be applied to your product. We invite you to take advantage of both Handy & Harman Brazing Alloys and Engineering Service.

GET THE FACTS

Technical Bulletins T-1 and T-2 give the general characteristics of silver brazing alloys plus the compositions, melt and flow points of 32 separate alloys. Write for your copies.



Your NO. 1 Source of Supply and Authority on Brazing Alloys

HANDY & HARMAN

General Offices: 82 Fulton St., New York 38, N. Y.

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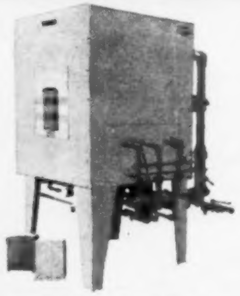
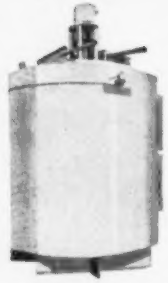
Wherever industry needs heat . . .

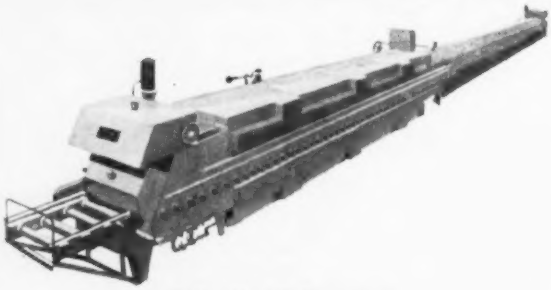
You'll find *LINDBERG* equipment just right for the specific job



Ceramic Kilns: Gas-fired periodic kiln (shown) with temperature range to 3250° F.

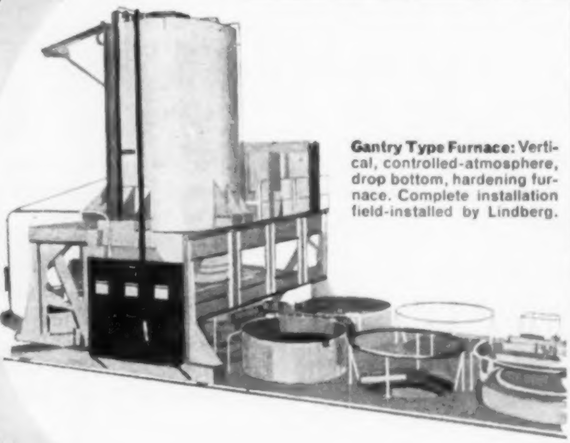


Vertical Type Furnaces: Carburizing and hardening furnace (shown) with CORRTHERM electrical heating elements.

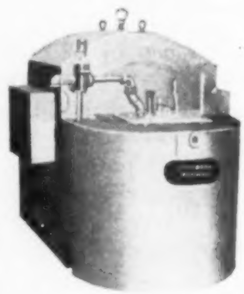


Roller Hearth Furnaces: Continuous electric type (shown) with temperature range 1300° to 2100° F.

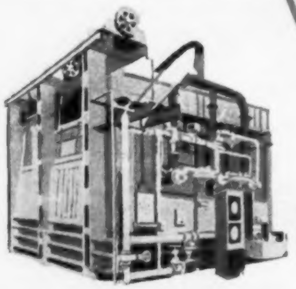
Laboratory Equipment: One-unit box furnace (shown), muffle or for non-oxidizing atmosphere with temperature range to 3000° F.



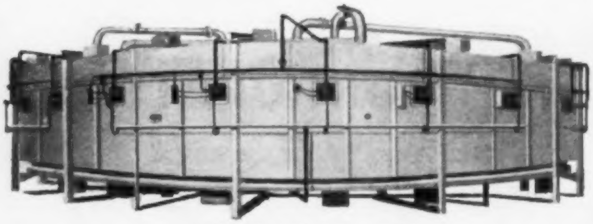
Gantry Type Furnace: Vertical, controlled-atmosphere, drop bottom, hardening furnace. Complete installation field-installed by Lindberg.



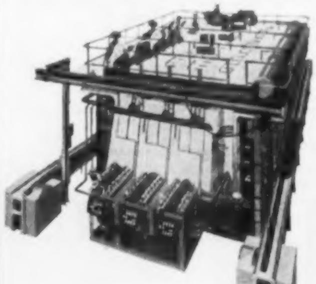
Melting and Holding Furnaces: Electric resistance furnace (shown) with capacities of 750 lbs. to 1500 lbs.



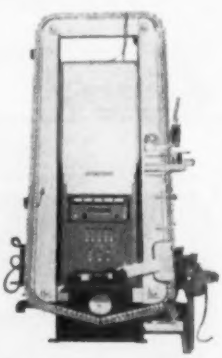
Aluminum Reverberatory Furnaces: Twin-chamber melting and holding furnace (shown) with 45,000 lbs. capacity.



Rotary Hearth Furnaces: Doughnut type field-installed gas-fired furnace (shown) with capacity of 13,000 lbs. per hour.



Multiple Row Pusher Furnaces: Three-row, vertical radiant tube pusher carburizing furnace (Shown). Capacity, 650 lbs. per hour to case depth of 0.055".



High Frequency Units: Vertically designed, completely automatic "HF" unit (Shown) for aluminizing automotive valves.


LINDBERG
Plus
CONTINENTAL

When Bell & Howell switched to Nialk Trichlorethylene with psp—permanent staying power, it extended clean-outs to a full three months.

How Bell & Howell degreases 390,000 lbs. of metal parts between bath clean-outs

When Bell & Howell switched to a Nialk® Trichlorethylene bath recently, it was found that bath clean-outs could be extended to a full three months.

Previously the bath had to be cleaned *every ten days.*

With the new Nialk bath, Bell & Howell is degreasing 195 tons of small camera and projector parts between clean-outs. The parts are aluminum, brass, steel and zinc and can all be cleaned in the same bath.

The secret is in the stabilizer
The only thing different about the Bell & Howell bath is the Nialk stabilizer. Light, heat, air and acids have no effect on the bath. Even aluminum fines, which can sour trichlor fast, have no effect in the presence of the Nialk stabilizer.

This stabilizer is not extracted by water either; hence all of it is reclaimed during distillation and steam injection. So permanent is the stabilizer that the bath stays fresh and fully protected at all times.

Bell & Howell simply adds more trichlor as drag-out losses lower the bath level; they never have to replenish the stabilizer itself.

FREE BULLETIN • The whole question of stabilizers is so important to anyone concerned with vapor degreasing, we've written a bulletin specifically on the Nialk stabilizer and its advantages. Write for Bulletin 70 if you'd like a copy.

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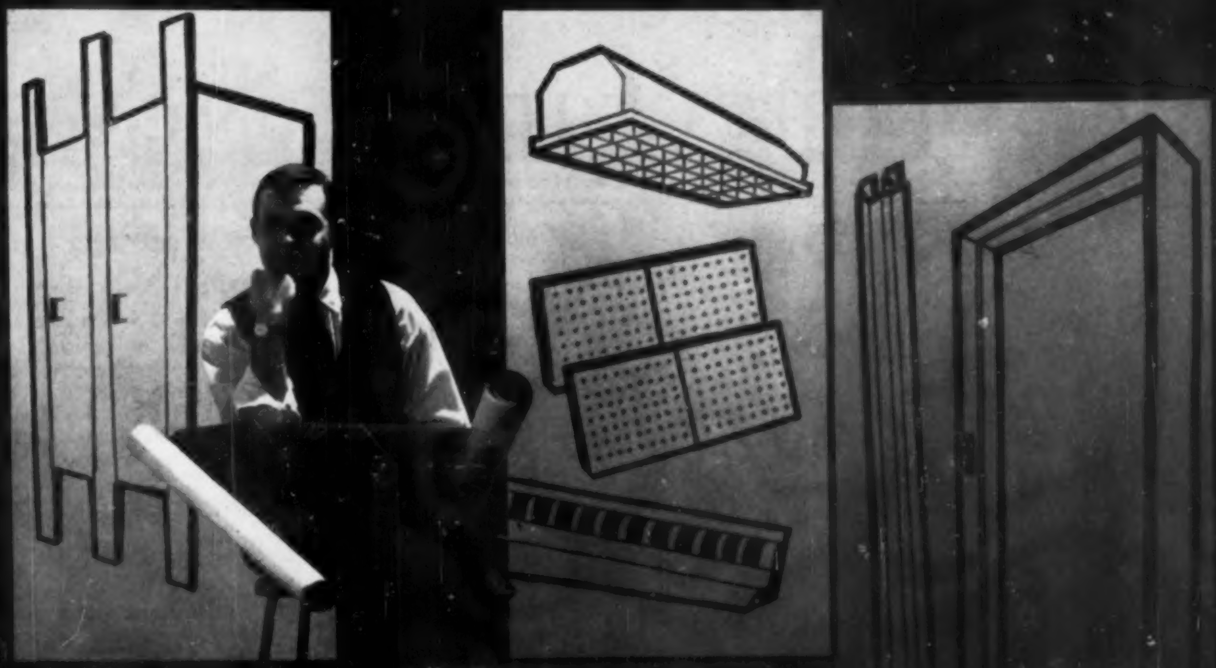
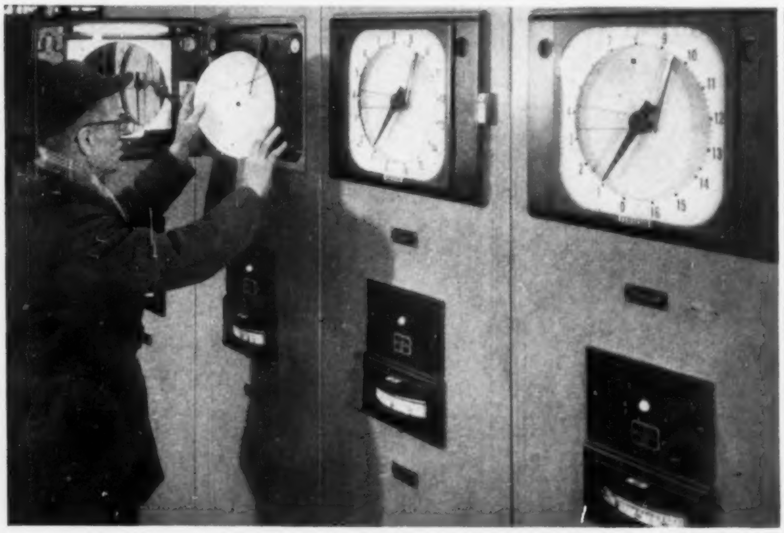


BRISTOL'S

Instrumentation News

• News of instrumentation and automatic control in industrial heating and metallurgy •



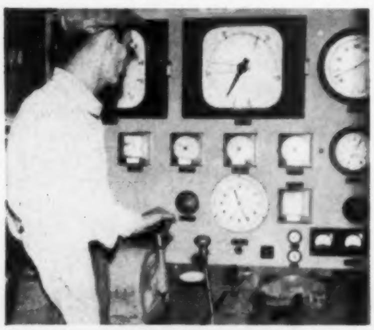
Instruments help turn out casting cores at 7 tons/hour

Engine blocks for Ford and Mercury automobiles are cast with strictest attention to accuracy and structural quality at the Cleveland foundry of the Ford Motor Company, Brookpark, Ohio, just outside Cleveland.

Yet these rigorous requirements must not impede the smooth flow of the production line. That's one reason Ford installed this battery of Bristol Dynamaster* instruments.

Another: In the early days, core baking used to be an all-night process. Cores were of fine quality, but the output was too low for present-day production lines. The new core baking method turns out top quality cores at the rate of 7 tons an hour. Bristol instruments automatically hold the baking temperature to 450° ± 5°F. And, in emergencies, allow faster processing by raising the temperatures and increasing conveyor speed.

First oxygen steel plant uses Bristol controls



Bristol round chart Dynamaster* Instruments (top) and Bristol Metagraphic miniatures (center row) play a big part in controlling oxygen steel-making at Dominion Foundries & Steel, Ltd.

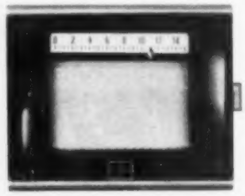
When Dominion Foundries & Steel, Ltd. (Dofasco), at Hamilton, Ontario, first introduced this method of steel-making to the North American Continent, they chose Bristol instruments and controls (above) to supervise the most critical steps in the process.

These include oxygen pressure and flow (current rate and total), lance position, lance cooling water temperature, flow, and pressure as well as various other temperatures.

The big advantage of oxygen steel-making is the lower original investment in equipment. Only about 50% of the equipment costs of competitive processes is required and operating costs are no higher, with equal or better product.

Furnace, oven, dryer— Bristol controls them all

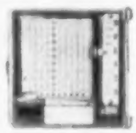
Whatever your industrial heating application, you can find a Bristol instrument or instrument system to provide precision indication, recording or automatic control. The following instruments, in almost innumerable variations, are typical of the truly complete Bristol instrument line.



Bristol's Dynamaster* Potentiometer Pyrometers come in round or strip chart models, provide electronic recording, indication, and electric or pneumatic control, including high-low contact, proportional, time-program and many combinations. The outstanding instrument for maximum precision.

Bristol Millivoltmeter Pyrometers. Both indicating and controlling models available. Controlling models utilize unique Bristol Free-Vane* principle that completely eliminates relay "chatter" or "flutter." High-low contact and proportional models available in a wide variety of combinations.

Bristol Miniature Instruments – Bristol is the only company offering a complete line of instruments in both miniature *and* full-size for all recording, indicating and control applications, both electronic and pneumatic. True plug-in construction. Ideal where panel space must be conserved.



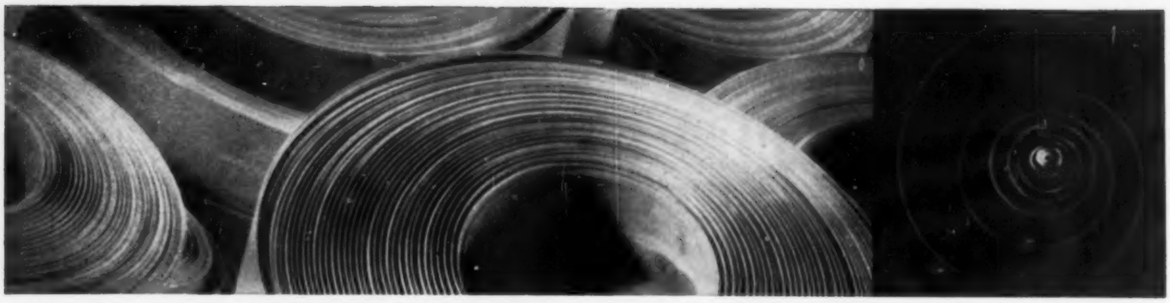
*T. M. REG. U. S. PAT. OFF.

Write for complete data on Bristol instruments for your furnace, oven, dryer or kiln. And remember, Bristol makes a complete line of thermocouples and pyrometric accessories. The Bristol Company, 106 Bristol Road, Waterbury 20, Conn.

B.26

BRISTOL TRAIL-BLAZERS IN PROCESS AUTOMATION

AUTOMATIC CONTROLLING, RECORDING AND TELEMETERING INSTRUMENTS



Check your requirements against these

Wallace Barnes Cold-rolled Specialty Steels

Furnished in these carbon grades:

1.25 – 1.32%   .90 – 1.05%   .70 – .80%   .59 – .74%   .48 – .55%

ANNEALED AND HARD-ROLLED

Thickness

.003 – .010″	in widths 1/8 to 6 1/4″	.036 – .049″	in widths 3/8 to 13″
.011 – .014″	" " 3/16 to 11″	.050 – .064″	" " 1/2 to 13″
.015 – .019″	" " 3/16 to 13″	.065 – .093″	" " 3/4 to 6 1/4″
.020 – .035″	" " 1/4 to 13″	.093 – .125″	" " 3/4 to 6 1/4″

HARDENED AND TEMPERED

Scale-free or scaleless; polished*; polished and blued*; polished and strawed*

Thickness

.003 – .004″	in widths 1/8 to 2″	.031 – .035″	in widths 1/4 to 7″
.005 – .007″	" " 1/8 to 3″	.036 – .040″	" " 3/8 to 7″
.008 – .009″	" " 1/8 to 4″	.041 – .049″	" " 3/8 to 6″
.010 – .014″	" " 3/16 to 5″	.050 – .060″	" " 1/2 to 4″
.015 – .019″	" " 3/16 to 7″	.061 – .064″	" " 1/2 to 3″
.020 – .025″	" " 1/4 to 8 1/2″	.065 – .093″	" " 3/4 to 3″
.026 – .030″	" " 1/4 to 8″		

*Maximum width for polishing in .010 – .030 thickness ranges is 5 in.

Facilities for processing alloy steels also are available.

Standard sizes normally available for prompt shipments.

Write for a copy of "Physical Property Charts" that give performance characteristics of .90 – 1.05% and .70 – .80% carbon grades.

Wallace Barnes Steel Division

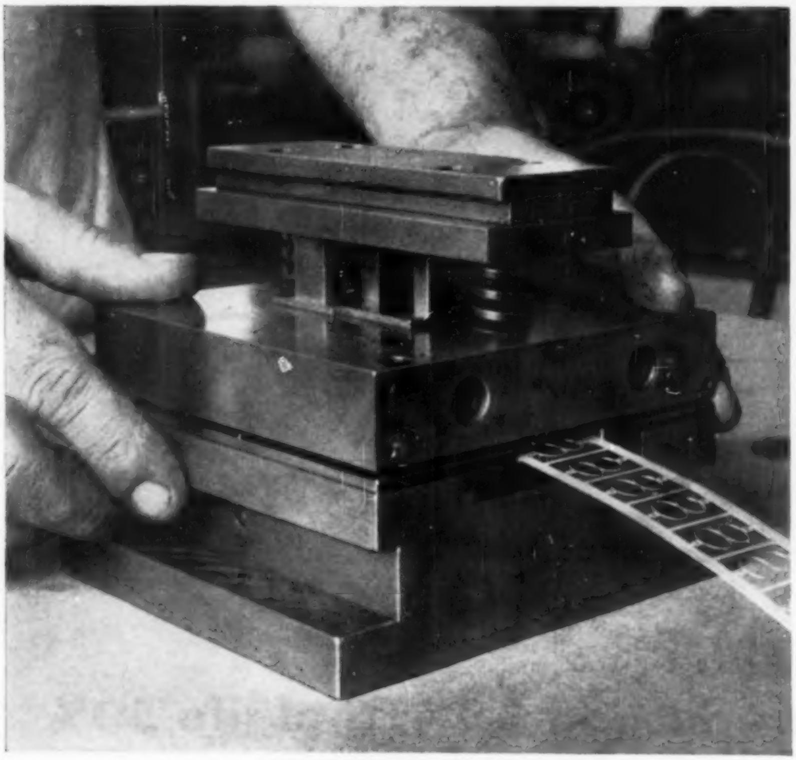
Bristol, Connecticut

Associated Spring Corporation

5818

Tool Steel Topics

On the Pacific Coast Bethlehem products are sold by Bethlehem Pacific Coast Steel Corporation
BETHLEHEM STEEL COMPANY, BETHLEHEM, PA.
Export Distributor: Bethlehem Steel Export Corporation



BETHLEHEM TOOL STEEL ENGINEER SAYS:

Heat-Treatment Is SO Important

Investigations of tool failures have shown that improper heat-treatment is responsible for a large proportion of the troubles. Adequate heat-treating equipment is often unavailable, or the equipment is operated improperly.

The importance of proper heat-treatment is often overlooked because it is relatively inexpensive as compared with the cost of the steel and the machining operations. However, just as the links in a chain must be equally strong, the heat-treatment operations on tools must be given proper consideration.

Whenever there is any doubt as to the adequacy of available equipment or its operation, it pays to look for help elsewhere. Commercial heat-treating shops, which are located in every section of the country, have the equipment, the ability, and above all, the experience to handle the heat-treatment of tools.

Die of Lehigh H Stamps Delicate Digits

The slim, digit-shaped stampings shown above are anodes, one of a series from 0 to 9, for a numerical indicator tube used in an electronic computer. They are made from several different metals. The width of the anode varies with each digit, and some are as narrow as 0.007 in.

Because of the extremely small clearances involved, the die maker, Be Cu Mfg. Co., Newark, N. J., decided to use progressive dies of a type previously used in producing sub-miniature parts. The dies were made from Bethlehem Lehigh H, supplied by our local tool steel distributor, Lindquist Steels, Inc., Elizabeth, N. J. And because of its low distortional characteristics, Lehigh H proved to be a wise choice.

TYPICAL ANALYSIS

Carbon 1.55	Chromium 11.50
Manganese 0.40	Vanadium 0.90
Molybdenum 0.80	

Lehigh H is our high-carbon, high-chrome grade of air-hardening tool steel. Outstanding because of its minimum size change during heat-treatment, it has the high wear-resistance needed for long-run jobs. Your Bethlehem tool steel distributor has it in stock. Give him a call today.

HOLLOW-BAR MINIMIZES MACHINING COSTS

Yes, you get greater economy in the shop, and a saving in material as well, when you use Bethlehem Hollow-Bar tool steel for any part requiring a center hole in the steel. We make Hollow-Bar by high-speed trepanning, which means coring out hammer-forged or hot-rolled bars, then rough-turning them on the outside. You can put the steel right to work, because the hole is already there. Two grades to choose from: BTR (Bethlehem Tool Room, oil hardening), and Lehigh H (high carbon, high chrome).

HIGH HONOR has come to *Metal Progress*. Its editor-in-chief and founder, Ernest E. Thum, has been elected an honorary member of the American Society for Metals. Following are excerpts from the citation read by C. H. Lorig, incoming president of the Society, at the annual meeting in Cleveland on Oct. 29:

> Honorary membership in the American Society for Metals is the highest honor conferred by the Society in recognition of one man's major contribution to metallurgy and the Society. Ernest E. Thum is eminently deserving of this award.
>
> He came to the Society 28 years ago to create a magazine which would be useful to the metallurgical industry; this year he became editor-in-chief of the publication which has achieved world prestige and a unique position as the magazine of metals engineering. The growth of *Metal Progress* in the intervening years has been guided by his keen insight into metal problems. His foresighted leadership, sound judgment and extensive metallurgical and editorial knowledge have kept *Metal Progress* continually in the vanguard of scientific and technical development.
>
> The American Society for Metals and the metals industry have profited further from association with Ernest Thum. His advice and help in all areas of A.S.M. activities have been a large factor in the phenomenal growth of the Society. . . .
>
> Mr. Thum's services to the profession and to A.S.M. are not measured by inventions or discoveries. Yet intangible though they be, his services have been of immeasurable value during the decades when proliferation of the printed word has frustrated the scientist and engineer with too much to read and too much to study. The responsibility for recognizing the important metallurgical developments as they occur, and the responsibility for presenting them in succinct and easily understood form are therefore tremendously important. Mr. Thum's wisdom in carrying the first responsibility, and skill in the second, have justly carved out his place as the "dean of metallurgical editors".

Critical Points

Behind the Brain: a Brain

What might be considered the ultimate in the use of brains – both human and electronic – in metalworking has recently been reached at Convair-San Diego. Not long ago a revolutionary new production theory was tried there. To say it worked to the complete satisfaction of all is somewhat of an understatement.

Before detailing the impressive achievement, let us set the stage by stating the problem.

In the development of missiles, both manned and unmanned, new aerodynamics theories must be tested on wind tunnel scale models before prudent people will authorize the expenditure of huge sums necessary to produce full-size machines utilizing these concepts.

The production of a scale model accurate in all details is in itself extremely expensive. Normally, to produce the model requires the making of drawings and the inevitable blueprints, lofting and the making of templates. As many as six months could be spent in going through these steps and the subsequent machining of the part.

Now to get to our primary story:

Designers at Convair developed a new wing concept and formulated an aerodynamic equation to translate it into reality. Among other things, the intricately contoured shape required an extremely thin leading edge. The equation was fed into a general purpose electronic computer along with other data concerning the machine tool movements needed to generate the desired surfaces. In due time a complete set of instructions for the machine tool came from the computer. The instructions were then coded and transferred to a magnetic control tape which took complete charge of the machining operation.

All of this, plus the actual machining of the wing shape, was done in about two weeks, thus saving almost 24 weeks of hard mental labor. The only hand work involved was choosing the proper cutting tool, clamping the workpiece in place and polishing down "peaks", 0.003 in. high, between machined paths.

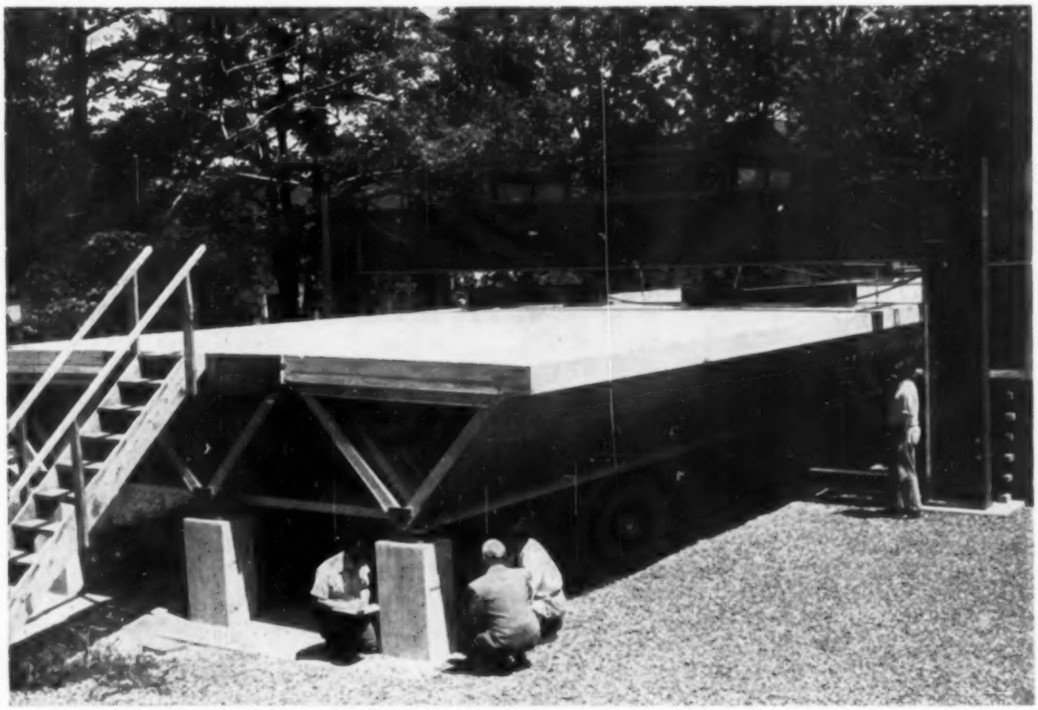
Sober contemplation of this entire operation makes one marvel at our new electronic marvels. About the only satisfaction to be salvaged by a mere human is the fact that all of the electronic wizardry is useless without a human brain in the background to supply it with raw material – that is to say, ideas.

T. C. DuM.

Bridges by the Dozen

Do you care to own a bridge? It's easy to do now. The Fairchild Engine & Airplane Corp. can build one made entirely of 6061 aluminum alloy in its Hagerstown, Md., factory and deliver it right to your doorstep. Provided abutments are available, your bridge can be installed in less than two days.

All of this interesting information was revealed at Lehigh University where the school's civil engineering department is now testing the prototype. Take a look at the picture. It illustrates the bridge section and the king-size fatigue testing machine which has shaken the section for the equivalent of over 100 years of actual use. The alloy used for the bridge is 6061 aluminum. It resists corrosion well and extrudes easily; both properties are essential for the design. Consisting of three triangular beams, 50 ft. in length, the test section is topped by a standard concrete roadbed. The beams, which are made of rolled aluminum sheet stiffened by aluminum extrusions riveted to the sides of each sheet, are bolted edge-to-edge to form the 24-ft.-wide roadway. Lightness and ease of fabrication of aluminum



Bridge Section and Testing Machine. During testing, more than 1,000,000 cycles of force (with loads up to 175% of design vehicular load limit) were applied to simulate at least 100 years of actual service

are also important; they make it possible to mass-produce bridge sections and truck them to bridge sites with minimum effort. Installation is also simple.

The questions might well be asked: Why mass-produce bridges anyway by this new technique? Is the market so large that building bridges in quantity pays? Well, the four aluminum producers (Alcoa, Kaiser, Reynolds, and Olin Mathieson) which are cooperating in this program think it is – and with good reasons. Consider this: From 60 to 70 thousand bridges will be needed for the limited-access highways to be built in the next few years. Under federal sponsorship, these highways will spread across the country. They will ride over innumerable rivers and local roads – and each river and road requires a bridge. With so many bridges needed, it's easy to see that a lot of time and money will be saved by mass producing them.

The metallurgist and designer are working together to give us more super highways for our dollar. We feel sure that many similar needs in the future will be filled by the same skillful combination. C.R.W.

"I Got Plenty of Nothin'"

In his September report on atomic energy, A. W. Kramer, editor of *Power Engineering,* briefly comments on that strange radiation the theoretical physicists have dreamed up – the neutrino. It is supposed to carry away about 5% of the power of a reactor, yet it is something which has neither mass nor electrical charge, nor magnetic moment. Therefore it cannot be stopped by any known means and one of these cosmic ghosts presumably could go clear through a hundred million suns before meeting its master. (I wonder how long that would take!) The only comfort in these days of hand-wringing over the biological effect of radioactive fall-out is that, even if these neutrinos cannot be stopped by any variety of shielding, organic, inorganic, electrical or magnetic, they should, by that same token, have absolutely no biological, chemical or physical effect. As Kramer says, you can't shield against *Nothing.* So apparently we have nothing to worry about except that 5% waste in energy.

E.E.T.

Forming Metals at High Velocities

By T. C. DuMOND*

Variously known as "high-energy-rate" and "explosive" forming, nearly a dozen new methods can be considered in looking for efficient and economical methods of shaping high-strength metals. Because of low die and equipment costs, the methods are particularly valuable for parts needed in limited quantities. Other advantages are elimination of springback and ability to handle extremely large parts. (G-general; NM-k34)

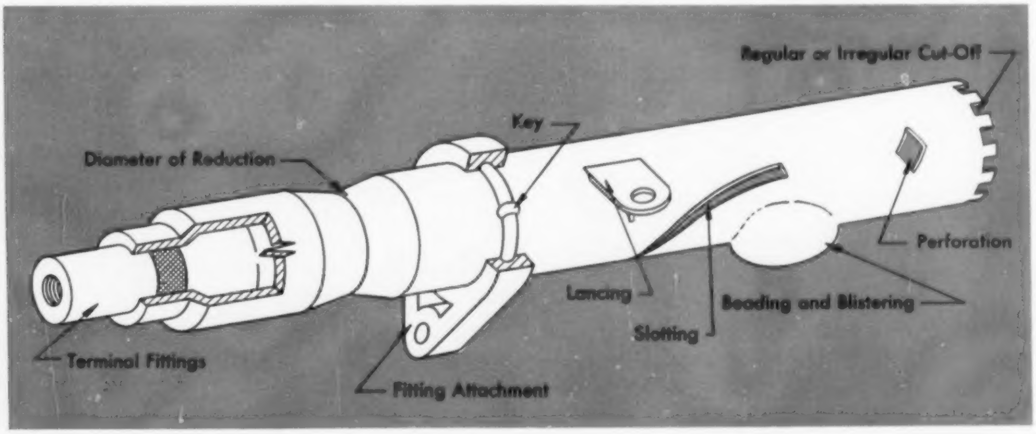
THROUGH ITS EFFORTS to find a simple method for forming large parts in high-strength sheet materials, the aircraft industry appears to be on the verge of perfecting a new production technique which could have wide influence in many industries. Although already popularly referred to as "explosive forming", the new method is more accurately known as "high-energy-rate forming".

Strictly speaking, high-energy-rate forming is not new. Explosives have been used for several years for simple dimpling and piercing operations, riveting, and for some flaring and bulging operations on cylindrical shapes. The newness of the process lies in its extension to the types of metal forming normally assigned to drop hammers, presses, brakes and stretch presses. Early and present uses of explosives to provide high energy are basically in connection with small parts. Now producibility engineers are also considering the possibility of forming huge parts which tax or exceed the capacities of existing press equipment.

High-energy-rate forming takes advantage of a long recognized, but little understood, metallurgical phenomenon. Researchers for many years have been aware that many metals will deform more readily under ultra rapid loading conditions than they will under ordinary rates of load application. It is not known why this condition exists and, until recently, there appeared to be no satisfactory method of applying relatively high pressure at extremely high speed.

*Mr. DuMond is secretary of the Metals Engineering Program Committee under whose direction the session on High-Energy-Rate Metal Forming and other William Park Woodside Panel Conferences at the National Metal Congress last month were arranged.

Fig. 1 – Engineers at Convair, Fort Worth, Tex., Consider All of the Operations Shown Here as Being Within the Scope of High-Energy-Rate Forming. Some of the operations would be extremely difficult or expensive by other methods. Difficulties in doing them by use of explosives will appear only as tooling problems



Much of the data for this special report were obtained from papers presented during the National Metal Congress, Oct. 30. Featured during the session were these papers:

"High-Energy-Rate Forming by Machine", by J. B. Ottestad, Chief Project Engineer, Hyge Machines, Convair, San Diego, Calif.

"Explosive Forming Under Water," by E. W. Feddersen, Chief of Manufacturing Research and Development, Convair, Fort Worth, Tex.

"Explosive Forming by Direct Application", by A. H. Petersen, Group Engineer, Producibility Methods, Lockheed Aircraft Corp., Burbank, Calif.

The session was headed by John Dorn, Head, Department of Metallurgy, University of California, Berkeley, Calif.

Early investigations showed considerable promise in the use of explosives to provide the required speeds and pressures. Thus, most of the research work up to the present has been with explosive charges. Recently a gas-actuated machine has been developed capable of supplying speeds and pressures of the same magnitude. Sketches accompanying this article illustrate the principal methods of using high-energy-rate forming. Conventional drawing and extrusion operations are performed at displacement velocities of from 1 to 5 ft. per sec. These speeds are in contrast to 100 to 400 ft. per sec. in high-energy-rate forming.

Why All the Effort?

It is natural to raise the question of why explosives and other high-energy-rate sources are being considered at all. There are several reasons. First, and possibly most important, is the fact that some method is needed to form satisfactorily the new aircraft materials which are difficult to shape by conventional forming methods. As the top strength limits of steels and other metals continue to climb, forming problems will become more general and more acute.

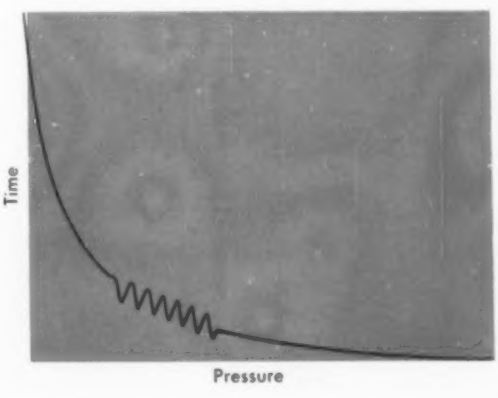
Second, existing press equipment, even though it has the power, is not capable of sufficiently high speeds to shape large sections of high-strength materials. Many of the high-energy-rate methods are ideally suited to shaping large sections. Presses having all of the attributes necessary for high-energy-rate forming would be prohibitively expensive.

Although not one of the original reasons for considering high-energy-rate forming, the fact that these methods virtually eliminate springback in forming stainless steels and titanium alloys has given additional impetus to their use.

Also of major importance is the matter of costs. Equipment costs can be held to an almost negligible point with several of the high-energy-rate forming methods. For example, some methods need nothing more in the way of equipment than a tank or a hole in the ground capable of holding water and of sufficient size to hold a die and blank. High-energy-rate forming requires only one die. Forming into a female die is done by shock wave, gas, water, rubber or other medium capable of transferring energy from the explosion to the blank being formed. Depending upon the method being used, die materials can range from such inexpensive and easily worked materials as wood, plaster and plastics up through the softer metals to the toolsteels.

Researchers investigating the use of explosives for high-energy-rate forming have borrowed heavily from other fields which have built up a large store of information on how explosives behave and how they can be controlled. One major principle borrowed from the field of explosive demolition is known as the Munroe effect

Fig. 2 — In Trying to Explain Why High-Energy-Rate Forming Produces Results, Some Researchers Believe the Shock Wave Produces a Hammering Effect at Its Low End. The entire action transpires in a few milliseconds



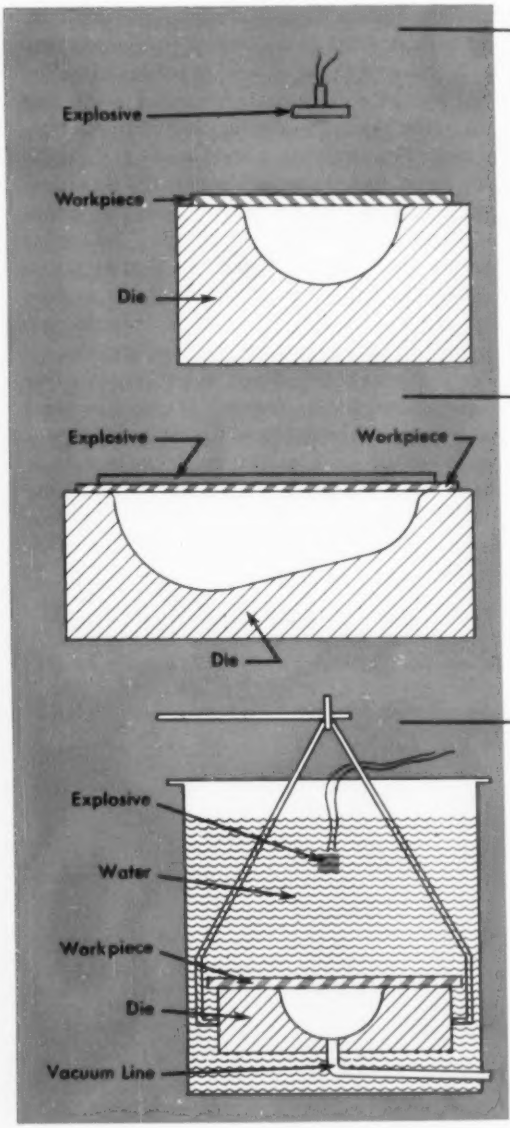
and is concerned with the use of shaped charges. A variation of the Munroe effect is sought through shaping the explosive to concentrate the charge in the desired direction and thus get preferential forming. Shaped charges are used to form complex shapes in high-strength metals.

Even though high-energy-rate forming is in its infancy, a variety of operations are being performed (see Fig. 1). Here are a few:

Dimpling – In one of the oldest applications, a cartridge is placed in a suitable fixture and when discharged it forces a ram carrying a dimpling tool into contact with the metal being formed. Forces can be controlled by varying the powder charge and the distance the ram travels. Similar techniques are used for piercing. Piercing of high-strength materials can be done without cracking the metal surrounding the hole and with virtually no burring, although there has been some difficulty with punch breakage.

Forming Hemispheres – Forming trials are being conducted by another group attempting to

Methods for High-Energy-Rate Metal Forming



Method A – In its simplest form, high-energy-rate forming consists of a female die, a workpiece or blank, and an explosive charge. The work can be done in the open without any fixtures other than the die half. No containers are necessary because the method does not use a transfer medium to direct the force over the workpiece. The degree of deformation can be varied by the size and shape of the explosive charge and the distance maintained between it and the workpiece.

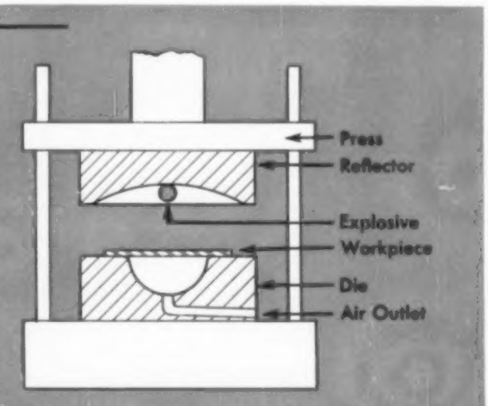
Method B – In a variation of Method A, the explosive in flat thin sheet form is applied directly to the workpiece. The explosive can be built up to any desired thickness, thereby varying the degree of energy released. Extremely high burning rates make the detonation practically instantaneous. This method is being investigated for joining dissimilar metals to produce composites without fluxes or adhesives.

Method C – Convair, Fort Worth, Tex., has developed this method, designated Dynaforming. Forming is done in water which can be contained in a pit or tank. Male or female dies are used. The blank is sealed to the die surface to keep water out of the cavity and a vacuum is drawn in the cavity to remove all air. The die and blank assembly is then suspended near the bottom of the pit or tank. An explosive charge is detonated in the water at a fixed distance above the workpiece.

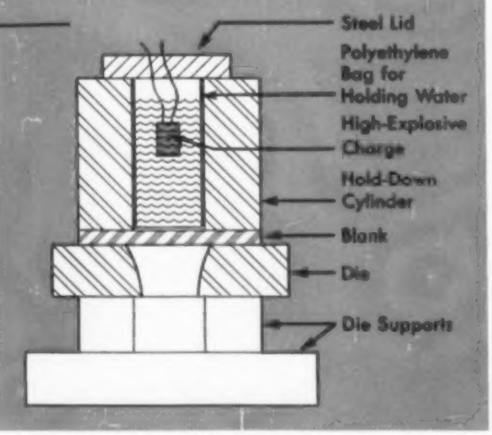
make hemispherical parts of constant wall thickness. It is hoped to form a shell with a wall thickness variation of only ± 0.0005 in. in materials ranging in thickness from 0.060 to 0.090 in. Currently minimum thickness variation is ± 0.004 in. in S.A.E. 1010 steel and annealed Type 302 stainless steel. Most of the dies have been made of reinforced epoxy plastics. Rolled and extruded explosives are being investigated, as are shaped charges, which will provide preferential forming of the shell.

Forming Hollow Inlet Vanes – In seeking methods of giving the final shape to inlet guide vanes, Ford Aircraft Co. turned to explosives. The vanes, made of commercially pure titanium and Type 321 stainless steel, are about 10 in. long, 0.050 in. thick and taper from 5½ in. to 3½ in. Heated vanes are placed in a heated die. The large end is seated against a stationary block which has openings for the passage of expanding gases resulting from explosion of a cartridge rated at 10,000 psi. The smaller end of the vane is held tightly against a solid adjustable block and when closed the die seals both ends of the vane. Gas pressure forces sides of the vane against two form blocks and gives the desired contour to the vane. There is no springback in the material, and shapes meet all inspection requirements. Tolerances as close as ± 0.005 in. can be held.

Forming Fan Hubs – Perhaps the longest record of forming by high-energy-rate methods has been logged by the Moore Co., Marceline, Mo. That company forms fan hubs in Monel, Types 316 and 321 stainless steel, cold rolled 1015 steel, silicon bronze and 1100 and 3003 aluminum alloys. All of these materials have been explosively formed in the annealed condition. Hubs formed are 12 in. in length, 3/16 in. thick; diameters range from 16 to 36 in. In forming the hubs, a seam-welded preform, somewhat smaller in diameter than the final part, is placed in the die cavity. Next a polyethelyne bag slightly larger than the inside diameter of the preform is placed inside the preform and filled with water. A dynamite charge is suspended in the water-filled bag and a lid placed over the die opening. When the dynamite is



Method D – In this method of high-energy forming, a shaped charge of high explosive is used in conjunction with a parabolic reflector. By this method, the metal is forced into the die through a shock wave and a pressure wave. To produce the desired form, the reflector and charge must be shaped to direct the explosive force in direct proportion to the deformation desired in the workpiece. In any use of shaped charges, the principles involved in the Munroe effect are utilized to create the desired results.



Method E – Hemispheres and cylindrical shapes can be produced in this variation of a free-forming high-explosive setup in which no die is used. The blank is placed over an open die ring. Above the blank is a hold-down cylinder which has an opening of the same diameter as the die. Inside the hold-down cylinder is a polyethlyene bag filled with water and containing the high-explosive charge. Tank ends as large as 10 ft. in diameter are to be made in aluminum alloys, and stainless and carbon steels. Many smaller pieces are now being made.

exploded, the metal preform is forced into the die and given its final shape.

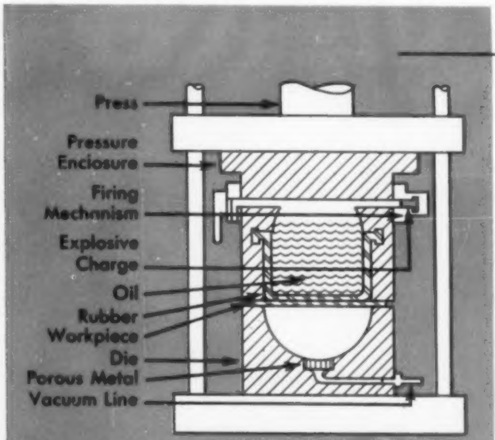
Forming Dished Parts – The Moore Co. also forms hemispherically shaped parts by using an open sleeve over which a blank is clamped. The steel sleeve takes the place of a female die. Another steel sleeve of the same inside diameter is placed on top of the blank and lined up with the bottom cavity. A polyethelyne bag, filled with water and containing a dynamite charge, is placed in the top sleeve and a lid placed over it. When the dynamite is exploded, it forms a piece of the desired shape.

Others are doing experimental work on tank ends using similar techniques. It is expected that the method will be used on parts up to 10 ft. in diameter in various aluminum alloys, stainless steels and carbon steels.

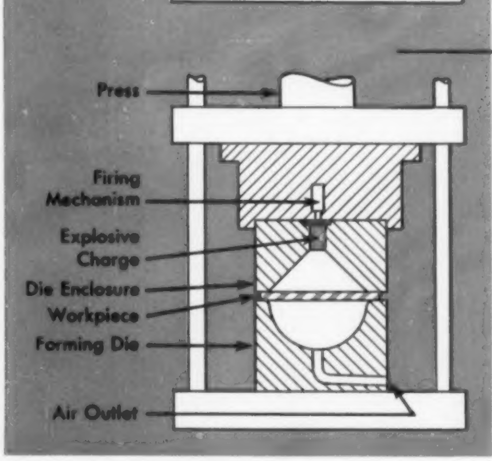
Swaging – Aluminum and steel sleeves of various sizes are swaged into wire rope by using high-explosive wraps. The metal sleeve, having about 0.010-in. clearance, is placed over the wire rope and then wrapped with a sheet explosive and detonated. The completed splice will exceed the strength of the wire rope in a tensile pull test. Explosives in cord form have also been used for this type of operation.

Bulging of Tubing – Many companies use explosives to bulge tubing of various sizes and in many materials. In one instance, a 4-ft. long, 10-in. diameter S.A.E. 1010 steel tube, ¼ in. thick, contains three distinct bulges some 17 in. in diameter. The blank tube is placed in a steel die and filled with water. Shaped explosive charges are placed at various locations in the tube and detonated. Because of the severe stretching involved, three successive forming and annealing cycles are required.

Embossing – Explosives are being used effectively to emboss metals either to create special effects or for lettering or identification. One method is to place waxed paper cutouts of the



Method F – Gunpowder or any other gas-producing propellent can be used in this type of closed system. Energy developed by the release of gas is transmitted through oil, water or some other medium and causes a flexible diaphragm to transfer the energy to the workpiece and develop the desired form as provided by the female die. In a system of this type, it is necessary that provision be made for removal of air from the die. The various components of the system are held in place by means of platen press.



Method G – Careful preloading of a low explosive (smokeless powder) gives a predetermined pressure in a given volume to develop the desired shape. Provision must be made for the escape of air from the die during forming. In this type of system, time of forming can be varied between 1 and 15 millisec. As with several other methods now being investigated, the entire assembly must be held in a press which can be opened and closed to insert and remove the workpiece and recharge the unit with the explosive and firing charge.

desired shape on the metal surface and detonate the explosive. The exact shape or design is duplicated in minute detail. Another approach involves the use of hair which is glued in place. The explosive force, creating the Munroe effect, will result in clear, deeply embossed designs. Still another was used to provide an "S" type spiral on rectangular tubing. A thin strip of rubber was placed on a piece of round tubing prior to its being explosively formed into its final rectangular shape. When formed, the embossed spiral had the exact shape and contour desired.

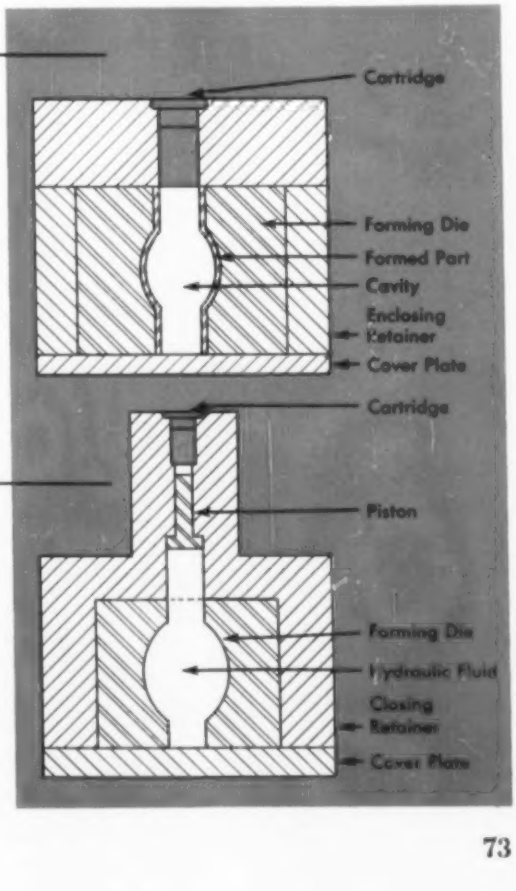
Many variations of the operations described are being carried on. Other interesting investigations include the use of explosives for surface hardening of metals. One research project has determined that copper and iron harden more from explosive shock waves than they do from the work hardening effects of a 95% cold rolling reduction. Dimensions, density and grain structure appear to be unaffected.

Du Pont reports the successful hardening of Hadfield's manganese steel by means of explosives detonated on the surface of the steels. In the practice followed, high explosives in sheet form are placed directly on the surface of the steel and detonated. Increased surface hardness is measurable to a depth of about 1 in.

Metals Formed – Although current interest in high-energy-rate forming centers about the use of the process on ultra high-strength metals and others which are difficult to form, many more common metals have been formed successfully. One researcher states that any metal having ductility can be formed through the use of explosives and other high-energy-rate methods.

Many theories and observations have been made about why metals are more susceptible to high-energy-rate forming. Until several current research projects are completed, most of these are likely to be in the nature of educated guesses. Some workers are inclined to feel that much greater elongation results when high energy rates are used. However, other researchers feel that metals formed by these new methods follow all the usual deformation rules – the major difference comes in the time interval during which forces are applied.

Formability of a material appears to be closely related to its plastic properties such as yield



Method H – Blank cartridges can be used for explosive types of high-energy-rate metal forming. In this instance, expanding gases resulting from the firing of the cartridge generate direct pressure against the metal causing it to assume the shape of the dies. Systems of this type and that shown in Method I, just below, are well suited to repetitive bulging operations on relatively small parts. When larger sizes are involved, some other variety of explosive forming would be more practicable.

Method I – In a cartridge-hydraulic system, a blank cartridge is again used. However, instead of using the direct pressure of the expanded gases to do the forming, the explosive forces actuate a ram which, in turn, forces a hydraulic fluid into the tubular blank and causes it to bulge into the closed die which surrounds it. Systems of this type can be used for blanking and shearing as well as for cupping and forming.

point or yield stress and degree of work hardening. In high-energy-rate forming, metals momentarily support stresses far beyond the elastic limit without deforming. In determining optimum forming speeds, it is often desirable that the critical impact velocity be known for each metal. Forming at rates other than the critical velocity fails to produce optimum elongation, and rates sufficiently above the critical velocity can cause rupture. For example, in forming thin ½-hard stainless, forming rates of a few feet per second make the difference between perfect parts and those which consistently tear.

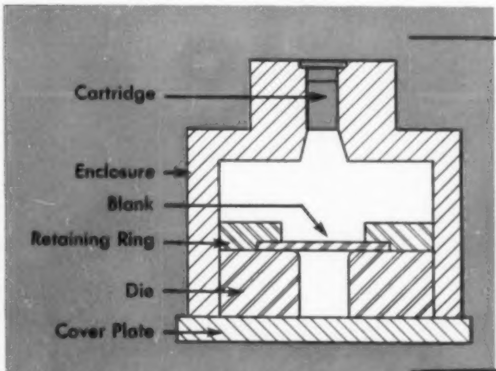
Many aluminum alloys are being formed explosively in both annealed and hardened conditions. Alloys include 7075, 1100, 3003, 2014, 2024 and 5086. Thickness ranges from that of foil up to ¾-in. 7075 plate.

Hardened precipitation hardening stainless steels, such as 17-7 PH and AM 350, are readily formable by the new methods as are many austenitic stainless steel grades and high alloys, such as 4130, 4340 and N 155 and high-chromium, high-nickel alloys which are extremely difficult to form by normal production methods. Included in the materials which ordinarily are somewhat difficult to form, primarily because of springback, are commercially pure titanium and Ti-6 Al-4 Y. Both are readily formable at high energy rates. Other metals successfully formed are low-carbon steels, brass and copper.

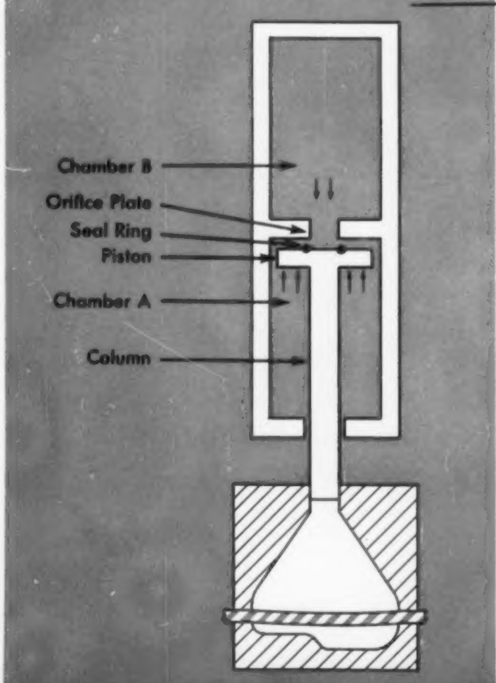
One company now carrying on extensive research on the formability of various metals reports that at present the high-energy-rate processes are not suitable for forming magnesium. Attempts to form several magnesium alloys with explosives resulted in shattering the materials.

Savings in Die Materials

Along with other actual anticipated advantages of high-energy-rate forming are the savings which can be realized in dies when compared with die costs for conventional forming methods. Savings are twofold. First, only one die is neces-



Method J – The cartridge method can also be used for cupping and drawing operations on small parts. The same advantages which exist in other high-energy-rate forming processes are also applicable to this method. If the depth of cup or draw is critical, the size of cartridge and the volume of space above the blank must be carefully calculated.



Method K – Although no explosive charge is involved, the quick release of energy by the Hyge machine developed by Convair, permits it to be used in high-energy-rate metal forming. A small pressure in chamber A closes the orifice in the center. When a gas under higher pressure (up to 2000 psi.) is released into chamber B, it is instantaneously translated into an extremely rapid forward motion of the ram. The Hyge machine can be used for sheet metal forming, forging, extruding, compacting of metal powders or ceramics, blanking and shearing and casting under high pressures. In using the machine for sheet metal forming, energy imparted to the ram is transmitted to the metal blank through a liquid medium contained in the upper portion of the die.

sary as compared to the two for most high-production forming processes. The majority of high-energy-rate forming methods employ female dies which are least costly to produce.

When it comes to the die materials, additional savings are also possible. No one die material appears to be ideal for all types of operations. In some instances, such materials as plaster, wood or concrete can be used for dies. When greater quantities of parts are required or more complex shapes are involved, soft alloys, epoxy resins or low-carbon steel might be used as die materials. For severe service, toolsteels will probably be used. Currently, epoxy resins and toolsteels are most frequently used.

Early experiences in using high-energy-rate methods for closed die forging indicate some difficulty in securing satisfactory dies that will withstand the terrific impact involved. The solution might be found in a new type of die design or a combination of die materials.

Explosives

When explosives are used for the energy source, the choice of explosive depends to some extent upon the forming system being used. Roughly, explosives are divided into high and low explosives. The detonation of a high explosive develops a shock wave which is utilized as a source of energy for forming. The force is used directly or transmitted through some transfer medium such as water. Example of high explosives are dynamite, TNT, PETN, RDX, tritonal and many special compounds. They are used in such forms as sheets, extrusions, pellets, shaped charges and primacord.

High explosives are usually combined with some other material to make them easier to handle and to provide more accurate control.

Low explosives function through burning which results in the rapid evolution of gases rather than by actually exploding. In high-energy-rate forming, the explosive force of the evolved gases is used to build up pressures in a closed container to the point where a metal blank will be deformed. Black powder, smokeless powder and ball powder are typical of low explosives. They can be used in blank cartridges, shot gun shells or any other form which will properly confine them and permit their firing.

Research Intensified

Although most workers feel confident that high-energy-rate metal forming has an important future, the majority recognize a need for extensive research. Already several major research programs are in progress.

In the area of basic research, John Dorn of the University of California has under way a program to try to learn precisely why metals can be formed more easily at high speeds. When this is learned it will be easier to apply high-energy-rate methods more efficiently.

Other researchers are not waiting for this information. It is known now that the process will work within certain limits. However, to save countless hours of trial and error in establishing a technique for producing a given part, it is necessary to determine by laborious study the effects of many variables. Some of these variables are the size, composition and shape of charge, location of charge and distance from the blank, and thickness and type of metal being formed.

Ideally, and the goal is in sight, charts will be prepared for various metals on which can be located the exact combination needed to produce a desired shape in any size and of any metal.

In addition, investigators are testing various energy transferring mediums to compare them with water which is now commonly used. Although many in the field are satisfied with water, others feel that a dry medium such as talc, foamed plastics or plastics beads might prove better.

There are divergent opinions as to what actually does the forming in those methods using transfer mediums. On the one side there are those who believe that the shock wave itself does the forming. Others are of the opinion that a gas bubble is formed in the liquid medium and is actually responsible for forcing the metal blank into the die. A third group believes that forming is the result of the transfer medium being pushed ahead of the shock wave. Research is being planned to determine which, if any, of these theories is correct.

In trying to explain why explosive forming can produce complicated shapes in difficult materials with a complete absence of springback, it is felt by some that there is a reverberatory action as a result of the blast which has a hammering effect on the metal. Research will seek to learn whether it is in fact the means of overcoming springback.

Future Uses

As with any new process, one can hear all manners of predictions as to the extent to which it will replace existing methods. So it is with high-energy-rate forming. However, some of the more conservative proponents of the methods

agree that the future of most of the methods presently considered lies more in handling sheet metal forming operations now beyond the reach of commonplace methods rather than in duplicating the results of those methods.

A typical part might be a large panel, which for strength purposes is deeply beaded. In some of the newer materials, a part of this type requires four strikes of a press with intermediate anneals. The same part could be formed in one shot by high-energy-rate forming and require only a final annealing operation.

Many of the high-strength metals now used or being considered for use in aircraft are subject to distortion upon annealing and quenching after forming. It is felt that high-energy-rate forming could be used for a final shaping and sizing operation which would not be of sufficient severity to require subsequent heat treatment. The fact that forming is done without having to contend with springback gives added appeal.

Up to this point, most emphasis in connection with high-energy-rate forming has had to do with the forming of sheet metal. There are, however, several other types of forming which show considerable promise. For example:

Forging – Both explosive charges and high-energy machines are being considered for forging. There are two prime reasons for research in this area. Forging with high-energy sources involves the same principles as sheet metal forming in that the rapid movement of metal permits forging of difficult materials in one shot. Also, forging of smaller parts, in particular, can be done with rather simple equipment. At the other extreme, explosive methods can provide pressures exceeding those of the largest forging presses now available.

Extruding – High-energy-rate methods using rams to transmit forces are also adaptable to the extrusion of metals. Wire and simple shapes have already been extruded. Before the method becomes commonplace, it will be necessary to find solutions to a few problems. It appears desirable that the extruded section should completely clear the die. However, when this happens under conditions where the billet is impacted at high velocities and the reduction is great, the velocity of the extruded section becomes quite high. It then becomes a problem to stop the extrusion after it leaves the die.

Compacting – Explosives and high-energy-rate machines will also be used in compacting ceramics, powder metals and metal and ceramic combinations. At the China Lake (Calif.) Naval Ordnance Test Station opposing pistons driven by high explosives apply millions of pounds of pressure to the powders to form metal disks. Similar methods could be used to provide dense compacts of materials too hard to handle in conventional compacting presses.

Casting – It is expected that some high-energy-rate metal forming techniques will be applied to casting operations. High-velocity flow of material could permit the casting of thinner sections and more complicated shapes by filling the cavities before the metal is chilled by cold walls of the mold.

Although much of the current interest in high-energy-rate metal forming centers about the aircraft and missile industries, it is logical to assume that other industries will adopt some of the methods before long. It is not difficult to see opportunities in the automotive field in the production of truck and automobile bodies in limited quantities. Manufacturers serving the chemical and petroleum industries might find in high-energy-rate forming a more economical method of shaping tanks, tank ends, heads, towers and other pieces of equipment involving large shapes made of high-strength materials.

Economics

The art of high-energy-rate forming is too new to have permitted the gathering of substantial cost comparisons with other processes. There are several obvious cost features which indicate strong advantages.

Most obvious is the case of extremely large pieces required in modest quantities. Press and die equipment for such production would be virtually out of the question. The only other alternative – hand forming – is also exceedingly expensive. Thus, high-energy-rate forming appears to meet a specific demand.

Even on small parts there are examples of appreciable reductions in cost favoring high-energy-rate forming. The savings result from reduced die and equipment costs and, in many cases, a reduction in the number of operations.

Although there is no question about costs becoming an important consideration in determining whether these new forming processes are suitable, costs are now secondary. Most companies actively studying the use of one or more of these methods are doing so because those methods seem to offer solutions to difficult forming problems. So at the moment formability, not cost, is the impetus behind high-energy-rate forming.

High-Temperature Metallurgy Today

By L. P. JAHNKE
*and R. G. FRANK**

Much of the recent progress in developing alloys for elevated-temperature service has been due to a better understanding of strengthening mechanisms which block the movement of dislocations to make deformation or slip more difficult. In this article, the authors survey the most promising areas for high-temperature development and give the best alloys among the light metals and steels. In Part II, next month, superalloys and refractory metals will be considered.
(Q24, Q-general, 2-62, 17-51; SGA-h)

WITHIN A LIFETIME the problems thrust upon physical metallurgy have increased vastly. But none has been more challenging or more urgently attacked than the need to use metals for stress-carrying applications at high temperatures. Nearly all work on this problem has occurred since 1940, a mere 18 years of effort. It was the advent of the jet engine in the early '40s that made rapid progress essential. A little later, the need to use nuclear energy sources increased the urgency, and the recent advances in rocket and space science have made progress in high-temperature metallurgy even more important. There are no signs that higher and higher temperature requirements will cease, though the road is becoming steeper and each forward stride more costly. In this article and Part II, which follows next month, a reasonably full picture of high-temperature metallurgy as it stands today will be given.

High-temperature behavior begins where low-temperature strengthening mechanisms start to fail. This is generally about 35 to 40% of the melting point of a metal and is marked by the existence of time-dependent phenomena, such as diffusion and recrystallization. The recrystallization temperature of pure metals depends on melting point as was shown by a chart in *Metal Progress* for October 1957, P. 113. Above each metal's recrystallization temperature, strength becomes strongly time dependent. Below, it is

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not. Thus it is possible to shift this time-dependent behavior to higher temperatures by changing to a metal system with a higher melting point. This, in fact, is how the big steps forward are taken, such as from aluminum to nickel. The smaller steps within each metal system depend upon understanding how low-temperature strengthening mechanisms fail and how their failure can be retarded.

Basic Strengthening Mechanisms

Metals are strengthened by blocking the movement of dislocations, thus making deformation, or slip, more difficult. This is true for both cold and hot service conditions. But at temperatures where the average thermal energy of the metallic atoms begins to strain their bonding forces, small thermal fluctuations allow the atoms to move, which generally affords relief of the dislocation pinning actions. Let us examine four primary pinning mechanisms and their reaction to high temperature.

1. Dislocation Pinning by Solute Atoms – This is often termed solid-solution strengthening and is caused by preferential segregation of the solute atoms near each dislocation. This mechanism works well at low temperatures, since the inhomogeneity makes dislocation movement more difficult. At high temperatures it is less effective for these reasons: First, the density of the solute cloud decreases and, thus, the strengthening ability is gradually reduced. Second, the cloud is no longer fixed but can drift along with the dislocation as it moves through the crystal. Thus, deformation is retarded but nevertheless occurs upon the application of stress sufficient to cause dislocation movement. Several investigators have analyzed this situation and found that velocity of motion (initial creep rate) is proportional to the product of the diffusion coefficient and the stress, so long as the stress is not large enough to break the dislocation away from the cloud. We can aid this strengthening mechanism by decreasing the diffusion rates of the solute atoms – generally by adding higher melting point metals. Little else can be done.

2. Dislocation Pinning by Short-Range Order – Here, the method of cold strengthening is reduced under hot conditions by two effects: First, the degree of short range order generally decreases as temperatures go up. Second, diffusion allows the disruption in the order (caused by dislocation motion) to repair itself quickly. Again, creep occurs at a rate proportional to the product of stress and diffusion rate, and nothing can be done to help except to reduce the diffusion rates by adding higher melting point, solute atoms.

3. Dislocation Pinning by Other Dislocations, Such as Cold Work – The effects of cold work disappear spontaneously at temperatures where diffusion allows recovery, recrystallization and grain growth (generally, above 40 to 50% of the absolute melting point). These processes lead to a restoration of the predeformation condition and a huge reduction in dislocation density. Careful control of deformation and subsequent recovery treatments can leave a higher dislocation density by the creation of a subgrain structure. This can retard the decay of this strengthening mechanism but at high temperatures, such as 60 to 70% of the melting point, it is doubtful that this is significantly beneficial.

4. Dislocation Pinning by Second-Phase Particles – The strengthening effect of second-phase particles seems to remain as long as the particles exist. Unfortunately, the particles are seldom thermodynamically stable and they either dissolve or small ones disappear and larger ones grow. This decreases the average density of particles and thus reduces their effectiveness as dislocation "pins".

This mechanism can at least be tampered with and its manipulation is a powerful tool for the high-temperature metallurgist. There are three possible routes: (*a*) employ slow diffusion rates, as before, by using higher melting point constituents; (*b*) arrange for secondary hardening by providing for formation of a second, more stable,

Table I – Metallic Elements Which Can Be Used as a Basis for High-Temperature Alloys

I. Too Scarce						
Ac	Ag	Au	Ge	Hf*		
In	Ir	Os	Pd	Pt		
Rb	Re	Rh	Ru			
Tc	Th	U	Y			
II. Melting Point or Density Undesirable						
Ag	As	Ba	Bi	Ca	Cd	
Ce	Cs	Cu	Ga	Hg	K	
Li	Mn	Na	Pb	Rb	Sb	
Sn	Sr	Te	Tl	Zn		
III. Remaining						
Explored Considerably						
Al	Co	Fe	Mg	Mo	Ni	Ti
Relatively Unexploited						
Be	Cb	Cr	Ta	W	V	Zr

*Hf may recently deserve to be put into Group III, as Cb has since 1955.

phase as the first phase coarsens or dissolves (toolsteels have this property); (*c*) most important possibility is to make the second phase more stable and relatively insoluble in the matrix (for example, Al_2O_3 in nickel or in aluminum).

It has been suggested by J. Fisher* that the remarkable strengthening attained by precipitation of a second phase can be explained if we presume the crystalline structure of the particles is perfect (that is, contains effectively no dislocations). If this is so, their strengths would approach theoretical maximums (say 10% of their elastic modulus) and their effects on retarding dislocation movement would be great. But they would lose this perfection as they coarsen.

Thus, we see that all four strengthening mechanisms fail more and more rapidly as temperatures rise above 40% of the melting point; only the fourth is significantly active above 70%. All fail because of atomic mobility which can be slowed only by adding higher melting point constituents or thermodynamically stable second phases. We would expect that the best alloys would consist of a matrix, in which atoms with low diffusion rates are dissolved, and in which are dispersed second-phase particles which are as hard, stable, and densely distributed as possible. As our story unfolds we will see that this is nearly always so.

*General Electric Co. Report 56RL1005.

Fig. 1 – Curves Portray Design Criteria for Aircraft Engines and Airframes. Generally designs are based on 70 to 80% of either the 0.2% yield strength or the 100-hr. rupture strength, whichever is lower. At temperature "A", which is 40 to 50% of the melting point, and corresponds roughly with the minimum recrystallization temperature of the base metal, we see that strengths become time dependent

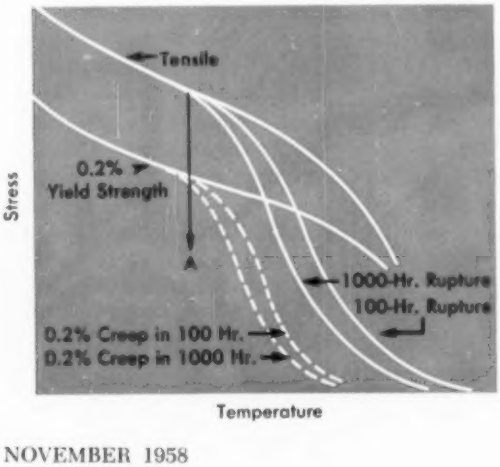

Table II – Highest Temperatures at Which Today's Best Heat Resistant Alloys Can Be Used

Base Metal	Melting Point	Temperature for Useful Strength of Best Alloys*	% of Melting Point†
	Light alloys		
Mg	1200° F.	650° F.	67%
Al	1220	550	60
Ti	3100	1200	46
	Superalloys		
Fe (Mart.)	2800	1350	56
Fe (Aust.)	2800	1600	63
Ni	2650	1960	78
Co	2720	1900	74
	Refractory alloys		
Cb	4470	2200	54
Mo	4760	2650	59
W	6170	2550	45

*Withstands 10,000 psi. for 100 hr.

†Per cent of absolute melting point at which alloy is useful.

The Over-All Picture

The number of metallic elements which we can use as basis for high-temperature alloy systems is remarkably few. Table I gives the picture. When we eliminate the very rare ones (these admittedly change somewhat with time) and those with unattractive melting point-to-density combinations, only 14 elements remain. Seven of these have been explored fairly extensively and alloys of them are commercially available for high-temperature applications. The other seven are still in the laboratory, so far as hot structural applications are concerned. Aluminum and magnesium have attained some use at moderate temperatures (up to 500° F.) largely because of their advantages of low density, low cost and availability.

Let us take a look at where we stand in high-temperature alloys today. Table II shows our position in each of the exploited systems. We see that useful strength has been preserved in nickel and cobalt alloys up to nearly 80% of the absolute melting point of the basis metal. (If we examine the melting point of the lowest melting phases in these alloys, this value is an amazing 85%.) It is doubtful if this 80 to 85% figure will be exceeded significantly. Titanium and iron (martensitic) have lagged primarily because of difficulties imposed by a phase transformation which occurs in each system.

The refractory metals are just beginning to be developed. Molybdenum is the furthest advanced, extensive work having been carried out

for the past six years; tungsten is the least, with essentially no alloy development having been performed. An indication of progress being made with molybdenum is the photograph on the cover of this issue of *Metal Progress* which shows a General Electric jet engine operating with turbine temperatures over 2000° F. using coated molybdenum buckets.

Thus, we are at a challenging "change point" in high-temperature metals. Having pushed nickel and cobalt to the end, and still needing more, we are forced into the extremely difficult problems of the refractory metals. The step that airframe and power plant groups are now trying to take to use molybdenum, columbium and tungsten is as difficult as the step made decades ago from canvas and wood for early airplanes to metal structures.

Fabrication Difficulties

As we increase in useful temperature, the costs generally rise both for raw materials and for machining parts. Aluminum and magnesium are inexpensive and available in all forms, but these systems are useful only up to 500° F. and not truly competitive with regard to strength even at lower temperatures. The best nickel alloys are difficult to machine, requiring perhaps 12 times as many hours per volume of metal removed as magnesium.

There are other problems: Titanium and molybdenum alloys require that forming be done warm – at 400 to 800° F. The best iron, nickel and cobalt alloys work harden rapidly and require many intermediate anneals with fast cooling to avoid precipitation of embrittling phases. A great jump in welding difficulty occurs in using the iron-base alloys. The martensitic alloys require pre and postheating, and the austenitic types are often subject to hot shortness and cracking. Fortunately, the nickel and cobalt-base alloys are less troublesome in welding. The alloys of molybdenum, columbium, and titanium require welding with inert-gas-filled chambers or else with extreme care to achieve excellent inert-gas shielding. Even then welds may be brittle at low temperatures – especially those of molybdenum.

In summary, the higher the temperature at which one requires strength, the more overwhelming become the costs. If we assume that a specific fabricated and machined aluminum alloy part costs $10, an identical part of a nickel-base alloy may cost $150. We pay for higher temperatures with dollars in more ways than one. This is one reason modern air weapons cost so much more than did those of World War II.

Design Criteria

Now let us inspect specific alloy systems, their strengths, faults and certain of their eccentricities. Comparative strength data will be presented in a manner used by designers of aircraft engines and airframes. Figure 1 presents various strength data, any of which could be used as design criteria for a specific part. Both fracture strengths (tensile and rupture) and deformation strengths (yield and creep) are included. At temperature "A", which is 40 to 50% of the absolute melting point and corresponds roughly

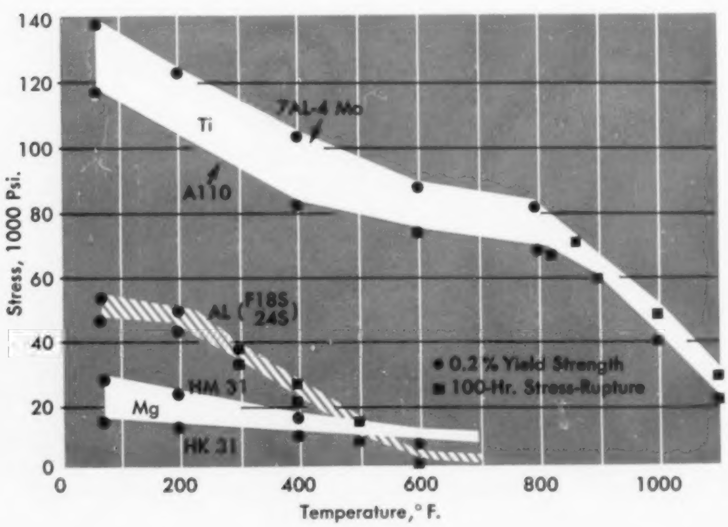

Fig. 2 – Strength Levels of Alloys Representative of the Best Available From Aluminum, Magnesium and Titanium for Elevated-Temperature Use

with the minimum recrystallization temperature of the base metal, we see that strengths become time dependent. The criteria for jet-engine design is generally 70 to 80% of either the 0.2% yield strength or the 100-hr. rupture strength, whichever is lower. For this reason these two values are used for subsequent comparison.

Light Metals

Alloys representative of the best available from aluminum, magnesium and titanium are shown in Fig. 2. All are strengthened by a second phase which requires heat treatment to control its size and distribution. In addition, titanium alloys are strengthened by solid solution of slow diffusing metals and strain hardening. It is easy to see why titanium is such a giant in its field. Even on a strength-to-weight basis, aluminum is far from being competitive and magnesium is less so. In the newest jet engines, magnesium and aluminum alloys can be used only for nonstructural members, such as gear boxes; in high-speed aircraft of the near future, whose entire structure is apt to be at 400 to 600° F. during operation, they will be even less useful.

Titanium alloys have gained a respected place but have turned out to be far from the panacea that was hoped for a few years ago. We shall see that for most applications they too are not competitive on a strength-to-weight basis with the best iron alloys (and surely not on a cost basis). New titanium alloys are emerging from laboratories now which will considerably raise their useful strength-temperature service range.

Titanium Troubles

Titanium had numerous production difficulties but nearly all have been solved. Machining is no longer considered difficult. Erratic variations from heat to heat occurred, but the reasons soon were understood and corrected. The most serious trouble found in both alpha and alpha-beta alloy types was caused by small amounts of hydrogen which came from sponge preparation, heat treating in reducing atmospheres, or pickling baths. A large amount of excellent work by several investigators allowed the problem to be isolated and solutions have been devised.

In alloys consisting of only the alpha titanium phase, it was found that hydrogen precipitated at low temperatures in certain crystallographic orientations as platelets of titanium hydride. These platelets had great deleterious effects on notched-bar strength but were practically unnoticeable in tests on smooth bars at normal strain rates. Impact strengths were, however, lowered precipitously by tiny increases in hydrogen content. In the two-phased alpha-beta alloys this did not occur due to the high solubility of hydrogen in the beta phase. But an inexplicable phenomenon known as "delayed fracture" was uncovered which created momentary discomfort in the jet-engine industry. The great mobility of hydrogen, even at low temperatures, plus the fact that the alpha and beta phases had different hydrogen solubilities, caused TiH_2 to precipitate at the phase interfaces. The most sensitive tests for finding the resulting embrittlement were long-time notched tests under constant stress. Figure 3 shows the enormous loss of stress-carrying capacity suffered by a good titanium alloy at room temperature due to very small increases in hydrogen content. Residual stresses, due to forming, were enough to cause parts to fracture in a few hours. Metallurgists were exposed to the shaking experience of having apparently good parts pop apart when they were placed on their desks overnight.

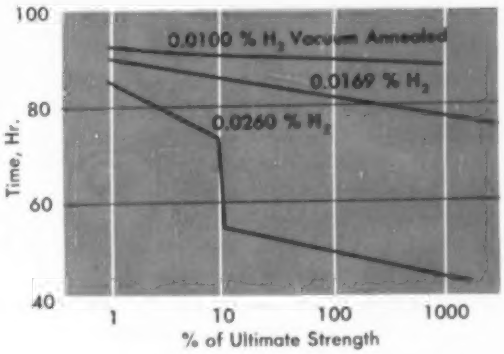

Fig. 3 – Effect of Small Amounts of Hydrogen on Stress-Carrying Capacity of a Good Titanium Alloy. Results are based on notched tests under constant stress with 8% Mn alloy

This resulted in establishing maximum hydrogen limits of 125 to 150 ppm. in finished parts, which effectively solved these embrittlement problems. Present production methods are successful in keeping hydrogen content low; if it exceeds 150 ppm., vacuum annealing treatments have been established which quickly reduce it to a safe level.

Steels Are Moving Up

Figure 4 presents the strength data for the more promising iron alloys. Halmo, Potomac M, and VascoJet 1000 alloys are typical of the

On the Cover

This month's cover portrays progress being made in the use of molybdenum. It shows a jet engine with molybdenum buckets operating above 2000° F. at G.E.'s Aircraft Gas Turbine Development Dept. in Cincinnati. The alloy employed was molybdenum containing 0.5% titanium. A five-layer coating was used to protect the buckets against oxidation: (*a*) chromium electroplate; (*b*) nickel electroplate; (*c*) flame sprayed brazing alloy; (*d*) Nichrome cladding (autoclaved into position); and (*e*) flame sprayed hard surfacing alloy. Over 500 hr. of engine test time was accumulated.

The rest of the engine was made of conventional materials either made thicker or cooled. The nozzle partitions presented a major materials problem which was solved by cooling in this test run. Generally, static parts can be made stronger by increasing their thickness but rotating parts cannot. Also, cooling is more difficult to devise for rotating parts.

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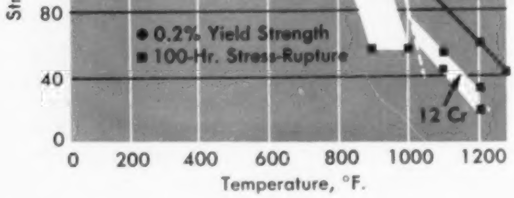
air hardening, martensitic toolsteels containing carbon and several carbide-forming elements. These alloys are subject to the difficult heat treating, welding, and fabrication problems which are expected from medium-carbon martensitic grades. When treated to give high strength, they possess low but adequate ductilities. On a strength-to-weight basis, nothing commercially available has been reported which is superior to such alloys from about 400 to 1000° F.*

AM 355, PH 15-7 Mo, and 17-7 PH are in a new class of alloys called the semi-austenitic steels. Their composition is designed so as to make them hover between austenitic and martensitic structures depending upon their heat treatment. The steels are formed and welded in

Fig. 4 – Strength Data for Promising Iron Alloys for Use in Elevated-Temperature Applications



the austenitic condition where they are ductile, and are then transformed to a martensitic structure by techniques such as supercooling. Containing about 15% chromium, they are quite corrosion and oxidation resistant (which the toolsteels are not). They have a balance of properties which is rapidly making them widely applied in the moderate temperature range up to 1000° F.

For extremely high stress applications the semi-austenitic steels are not competitive with toolsteels, but for general applicability they are easier to use. Variations in their composition must be closely watched to protect the delicate balance of crystalline structure. For instance, heating thin sheet in a high-nitrogen atmosphere can allow enough nitrogen to dissolve to stabilize the austenite, and the material will not respond to hardening treatments. Certain irritating troubles have been due to transformation to martensite during severe cold work, and distortion of parts due to the austenite-martensite phase change has been encountered. However, a large number of successful applications are being made in the airframe, jet-engine, and missile industries.

The 12% chromium stainless martensitic alloys, such as Lapelloy, are an older class which has found wide use in steam turbines. Literally dozens of similar compositions have been developed. This group of alloys is not receiving much development attention now, nor is significant improvement probable. They are, however, the strongest of the martensitic iron alloys above 1100° F.

*A new all-beta titanium alloy (B 120 VCA), developed by Crucible Steel Co., is becoming more competitive in this area.

Two New 1800° F. Alloys for Cast Turbine Blades

Nicrotung *By J. T. BROWN**

LIKE JET PLANES and missiles, new alloys also come from the drawing boards these days. At any rate, they are designed much as any new car would be. In our work, principles learned from extensive research and production experience were applied to the development of our new superalloy, Nicrotung.

In the initial stages, designing a new superalloy, even though it is intended to reach stresses and temperatures beyond the capabilities of any now known, is really not as mysterious or as difficult as one might first imagine. We used what could be called an "empirical scientific approach". The knowledge gained from data gathered on commercial high-temperature alloys and techniques for processing them, plus that obtained from sound, fundamental research on mechanisms contributing to high-temperature strength, can be integrated into the design.

To begin with, our objective with "Nicrotung" was to create an alloy having a 100-hr. stress-rupture strength of 20,000 psi. at 1800° F. At the same time, it had to have the features needed to enable its production by present techniques. In its development, certain basic metallurgical principles were followed. The selection of constituents and their amounts was based in part on a considerable background of experience in high-temperature alloys. Nickel was chosen as the base element because it is the most practical high melting point element for 1800° F. service. Chromium confers oxidation resistance on the nickel-base alloy. We decided further that an improved alloy would result if the solid solution were to be hardened by the addition of an element with a large atom (we used tungsten) to the limit of solid solubility. Properties of the

*Metallurgical Development Section, Materials Engineering Dept., Westinghouse Electric Corp., Pittsburgh.

DCM Alloy *By J. E. WILSON**

DCM Alloy was evolved from a statistically designed study of 27 compositions involving variation of three levels of three elements each. At 1800° F., the alloy selected from these experiments gave an average stress-rupture life of 525 hr. at 15,000 psi. Named with the initials of its developers, E. L. Dunn, M. E. Cieslicki and J. B. Moore (who at the time were in the materials engineering section of General Electric's jet engine department), DCM alloy is a contender for the top spot as the strongest nickel-base alloy melted in production quantities. It is considered the best alloy available for its stress-temperature range of operation.

The preferred composition range (wt.%) of DCM is as follows: C 0.08 max.; Mn 0.10 max.;

*Specialist-Engineer, Metallurgical Engineering, Jet Engine Dept., General Electric Co., Cincinnati.

Nicrotung

nickel base were enhanced by adding some cobalt, but not enough to exceed the solid solubility limits.

Precipitation hardening, by dispersion of small particles of a second phase, was accomplished by adding titanium and aluminum. Finally, additions of small but critical percentages of boron, zirconium, and carbon were made to improve the alloy. The nominal composition is: 12% Cr, 10% Co, 8% W, 4% Al, 4% Ti, 0.10% C, 0.05% B, 0.05% Zr, bal. Ni.

The alloy was developed as a cast material with no heat treatment required. Castings have a hardness of Rockwell C-37 to 40. We vacuum melt 1000 lb. of bar stock. This is then used as remelt stock for smaller arc furnaces using an argon atmosphere to blanket the melt. Parts are made by pouring into precision-casting molds in the normal manner.

Mechanical Properties

More than 40 experimental heats were made; they provided more than 200 precision-cast specimens (0.25 in. gage diameter) which were used for tests. The average results are presented in Fig. 1 and 2.

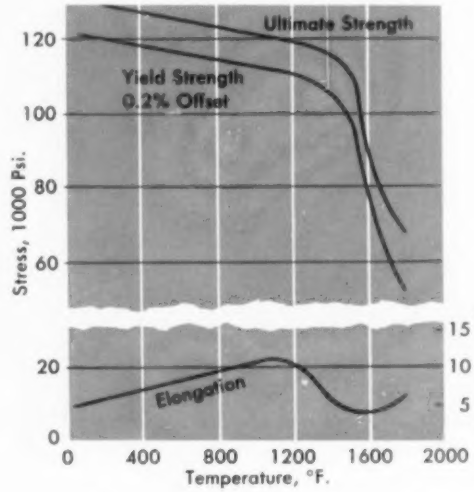


Fig. 1 – Mechanical Properties of Nicrotung at Various Temperatures

Both fatigue strength (27,000 psi. at 1800° F.)

DCM Alloy

Si 0.15; S 0.015 max.; Cr 14.0 to 16.0; Ti 3.35 to 3.65; B 0.070 to 0.090; Al 4.4 to 4.8; Mo 4.5 to 6.0; Fe 4.0 to 6.0; Cu 0.10 max.; Ni balance. Heats up to 1000 lb. have been produced by vacuum induction melting. Blades are produced from the master melt* by investment casting in vacuum. Some of the physical properties of DCM needed for design data are given in Table I. It will be noted that the density of the alloy is in the same range as U-500, Type 403 stainless steel, and A-286.

Variables Studied

One of the major stumbling blocks in developing design criteria for the alloy was the wide variation in rupture life which resulted from confirmation testing for design data. Many variables were investigated including: (*a*) method of addition of reactive elements; (*b*) partial additions in the master melt with final additions in remelts; (*c*) time allowed for various phases of melting; (*d*) effect of cast configuration; (*e*) effect of vacuum remelting; and (*f*) effect of grain size.

By far the most significant variable was found to be grain size (see Fig. 1 showing effect of

*DCM is being vacuum melted by Austenal, Inc., Dover, N.J.; Cannon-Muskegon Inc., Muskegon, Mich.; Haynes Stellite Co., New York; Metallurgical Products Dept., General Electric Co., Detroit; and Utica Metals Div., Kelsey-Hayes Co., Utica, N.Y.

Table I – Physical Properties of DCM*

Density (at room temperature)	0.286 lb. per cu. in.
Coefficient of linear thermal expansion†	
100 to 500 °F.	7.21
100 to 1000	7.71
100 to 1500	8.78
100 to 1800	9.94
Thermal conductivity‡	
100 °F.	78.1
200	90.5
300	102.6
400	114.9
500	127.6
600	139.9
700	152.0

*All measured points within ± 1% of mean values.
†In in. per in. per °F., $\times 10^{-6}$.
‡In Btu. per sq. ft. per in. per hr. per °F.

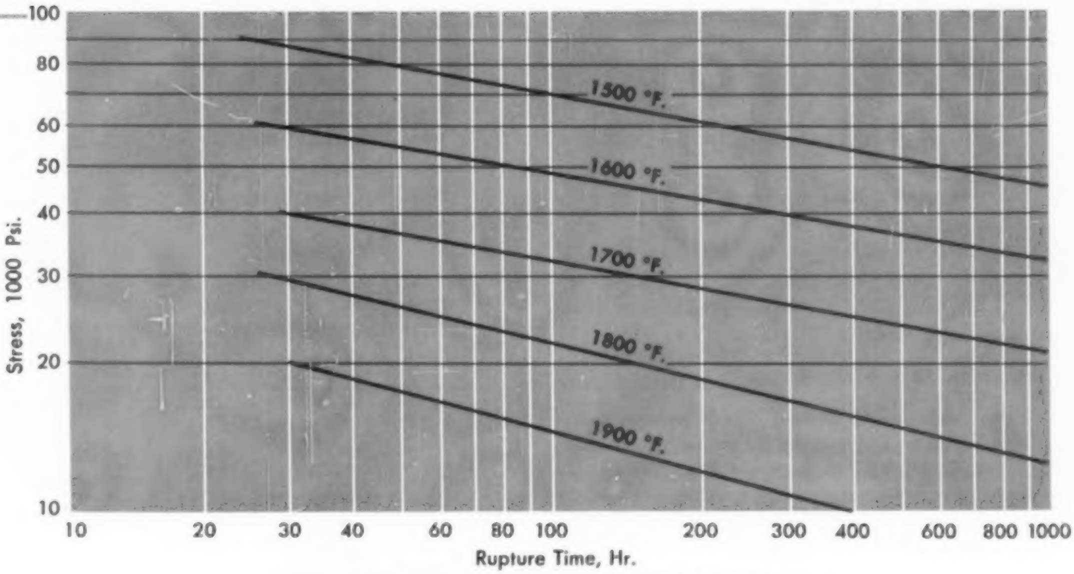


Fig. 2 – Stress-Rupture Time at Several Temperatures

and elastic modulus (25.7×10^6 psi. at 1600° F.) were substantially better than those of any comparable alloys.

During our experimental work, we tried several different atmospheres for both melting and casting Nicrotung. These were as follows:

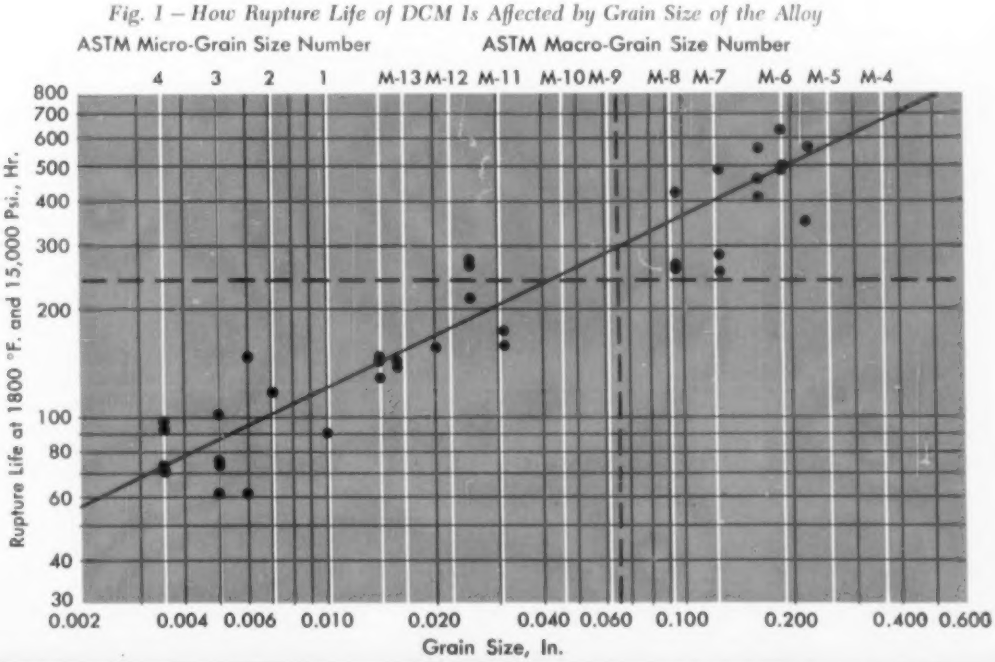
1. Vacuum melted and vacuum cast.
2. Vacuum melted and argon cast.

(Continued overleaf)

grain size versus rupture life). There have been many statements on how grain size affects various properties of cast alloys. However, we feel that for DCM a quantitative relationship has been established. The rest of the variables given above were investigated and appeared to have little or no significant effect on the alloy.

From the grain size study (see Fig. 1) it can be seen that as the average grain diameter increases from 0.0035 to about 0.200 in., rupture life of DCM, measured at 1800° F. and 15,000 psi., increases from 70 to 500 hr. This is an

Fig. 1 – How Rupture Life of DCM Is Affected by Grain Size of the Alloy



Nicrotung

3. Vacuum melted and air cast.

4. Vacuum melted-remelted under argon and argon cast.

5. Vacuum melted-remelted in air and air cast.

6. Argon melted and argon cast.

7. Air melted and air cast.

Both vacuum and argon melting and casting resulted in good properties. When melted or cast in air, the alloy displayed poorer and less predictable properties.

Carbon, Boron and Zirconium

As we mentioned before, small amounts of carbon, boron and zirconium improved the stress-rupture strength and ductility of Nicrotung-type alloys. To confirm this, a series of eight heats was cast using the composition detailed in Table I. Stress-rupture tests at 1800° F. were used to evaluate the heats relative to each other. Conclusions from this experiment indicate:

1. Without at least some minimum level of carbon, boron or zirconium in the base alloy, sound castings can't be made.

2. Carbon appears to be the best for increasing the strength, followed by boron and zirconium.

3. The combination of any two elements is better than any one.

4. When all three elements are used, by far the best alloy results.

Table I – Composition and Stress-Rupture Properties of Nicrotung Alloy

Heat No.	C	B	Zr	Rupture Time*	Elongation*
1	—	—	—	†	†
2	—	—	0.05	2.3 hr.	2.0%
3	—	0.05	0.05	24.2	2.9
4	0.10	—	—	18.8	2.4
5	0.10	0.05	—	22.5	2.0
6	0.10	—	0.05	23.9	2.2
7	—	0.05	—	13.6	2.5
8	0.10	0.05	0.05	71.8	4.6

*At 1800° F. and 25,000 psi.

†All specimens were broken when removed from the mold. No X-ray defects were found in the broken specimens.

DCM Alloy

amazing range and is probably greater than for other nickel-base alloys.

Rupture life of DCM, covering a wide range of temperatures and stresses, is compared with some other alloys by the Larson-Miller parameter given in Fig. 2. Creep tests have indicated 0.2% plastic creep strength to be 9000 psi. at 1800° F. However, these data were from bars with exceptionally fine grain size (micro). It is believed that this value can be increased with larger grain size. Elevated-temperature tensile properties of DCM are shown in Fig. 3. It will be noted that ductilities are in the range of most cast alloys. However, design engineers are learning to "live with" cast ductilities.

The pneumatic fatigue strength of DCM alloy in completely reversed bending remains constant from 1300 to 1700° F. at about 35,000 psi. This

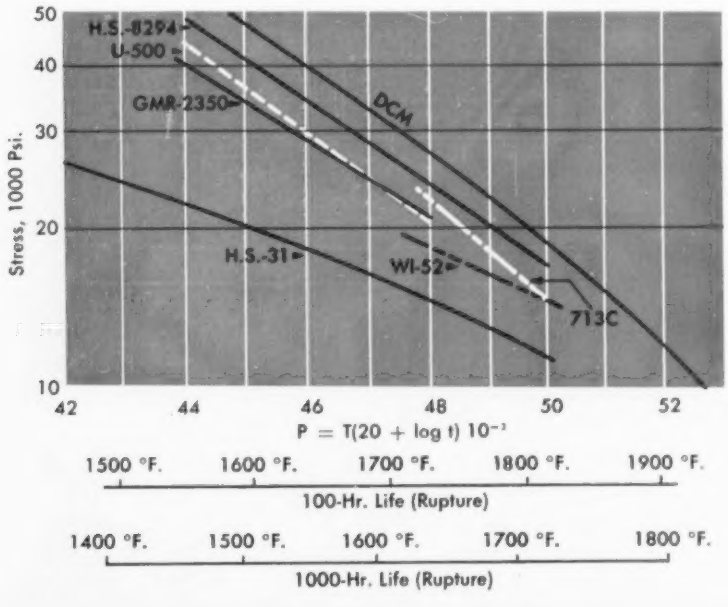


Fig. 2 – Comparison of DCM With Other Superalloys on the Larson-Miller Parameter Diagram

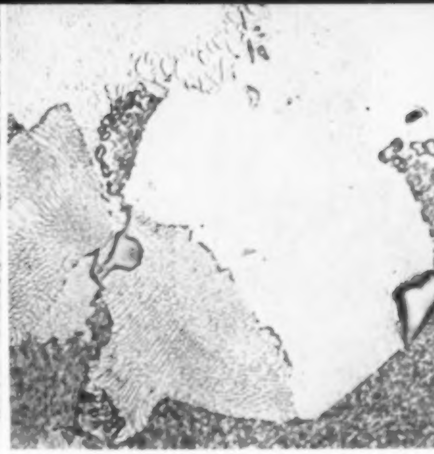


Fig. 3 – Microstructure of Cast Nicrotung. Note dendritic structure at 100 × (above), and single-phased structure (with a teardrop-shaped second phase) at 500 ×

Microstructure

Although the alloy is complex, the microstructure is not too difficult to understand. Essentially, it consists of a solid-solution matrix, with a small amount of teardrop-shaped second phase which generally occurs at grain or subgrain boundaries. Figure 3 illustrates the dendritic as-cast structure (100 ×) and a 500 × section in which three inclusions are evident. The different shading of the grains is caused by their different orientations.

Summary

At present, the alloy has passed initial requirements for higher temperature turbine blading material. Due to its designed composition, time and cost of development have been considerably reduced, and the goal of stress, temperature, and time (20,000 psi., 1800° F., and 100 hr.) to rupture has been exceeded.

The alloy is now in production and is undergoing extensive jet engine testing at our Aviation Gas Turbine Div.

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is equivalent to the strength of cast Udimet 500 at 1200° F.

The fact that the fatigue strength was at approximately the same level for 1300, 1500 and 1700° F. is highly significant because most other turbine blade alloys (Nimonic 80-A, Nimonic 95, Waspalloy, X-40, for example) lose part of their fatigue strength before 1600° F. is reached.

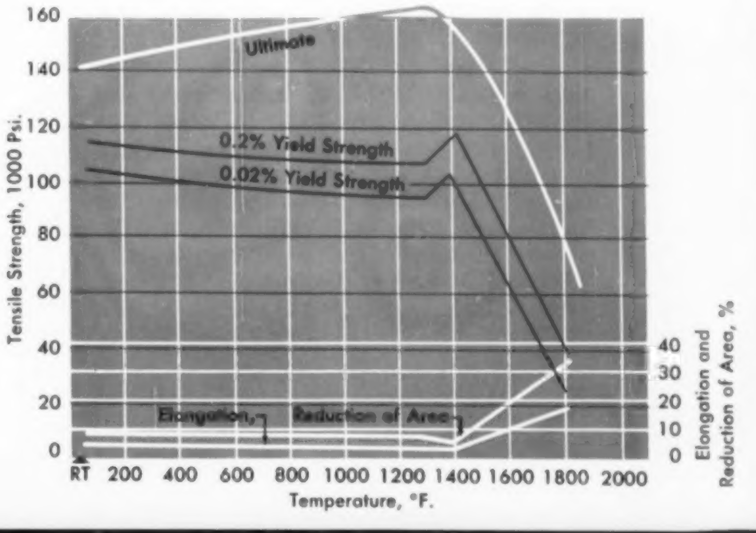
Heat Treatment and Microstructure

The heat treatment procedure used for the DCM data presented here is as follows:

1. Solution at 2100° F., 1 hr., air cool
2. Age at 1950° F., 2 hr., air cool
3. Age at 1550° F., 4 hr., air cool

Besides the phase called gamma prime Ni_3-(Al, Ti), a complex boride phase (M_3B_2) and a Ti (C, N) phase are found in the as-cast condition. After heat treatment, the carbide phase $M_{23}C_6$ forms at the expense of the Ti (C, N) phase. Low rupture life, attributed to fine grain size, is believed due in part to $M_{23}C_6$ and/or gamma prime agglomerate in the grain boundaries of the cast alloy.

Fig. 3 – Tensile Properties of DCM Alloy at Elevated Temperatures. Heat treating schedule: 2100° F., 1 hr., air cool; 1950° F., 2 hr., air cool; 1550° F., 4 hr., air cool



Tempering Type 410 Stainless Steel

*By CHARLES F. LEWIS**

An adaptation of the Hollomon-Jaffe tempering parameter has made it possible to devise simple charts, usable by shop personnel for tempering Type 410 stainless steel. Retempering has been cut to a minimum. (J29, SS)

How can you consistently temper a steel whose hardness drops from Rockwell C-40 to C-30 with a rise of only 60° F.? That, essentially, was the problem we faced in tempering Type 410 stainless steel for oil well tools. A look at the tempering curve of Fig. 1 will reveal that this steel stays at the as-quenched hardness (C-44) to around 980° F.; the hardness then drops abruptly, and reaches C-27 at 1100° F. Consequently, tempering in this range is akin to stopping for coffee halfway down a ski jump. We eventually solved it by adapting the Hollomon-Jaffe† tempering curves to produce a simple chart which could be readily used by shop heat treaters. While not completely effective (due to variations in chemical analysis and as-quenched hardness), our retempering operations have been considerably reduced.

Relatively speaking, little has been done quantitatively with the tempering operation in heat treating steels. Much of the meager published work concerns only plain carbon or very low-alloy materials, and most of the work used statistical analysis techniques to relate final hardness to known chemical analysis of the heat.

Hollomon and Jaffe, late in the last decade, found that final hardness can be adequately estimated by the following parametric equations:

$$P = T\ (a+\log_{10}t)$$
$$H = f\ (P)$$

where T is the absolute temperature (° F.+460), and t the tempering time expressed in hours. The hardness (H) may be expressed in any convenient units. Here, we have used Rockwell C. For a given material, the hardness for various values of the parameter must be determined experimentally to obtain the hardness-parameter function. Thus, tempering to a given parameter value, determined by any one of several combinations of time and temperature, results in a given hardness. Within statistical limits, equal parameters will yield equal hardnesses.

Supplementing this work, Nehrenberg and Bloom* contributed data on the use of this parameter in tempering the stainless group including Type 410. They agreed that a value of 20 for the constant (a) was adequate, a reasonable variation in this figure having little effect on the estimated final hardness.

We have combined the data of Nehrenberg and Bloom, published data from steel company

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*Metallurgical Engineer, Cook Heat Treating Co. of Texas, Houston, Tex.

†"Time-Temperature Relations in Tempering Steel", by J. H. Hollomon and L. D. Jaffe, A.I.M.E. *Transactions*, Vol. 162, 1945, p. 223.

*"Master Curves Simplify Stainless Tempering", by A. E. Nehrenberg, *Steel*, Vol. 127, Oct. 23, 1950, p. 72.

"The Effect of Heat Treatment and Related Factors on the Straight Chromium Stainless Steel", by F. K. Bloom, *Corrosion*, Vol. 9, February 1953, p. 56.

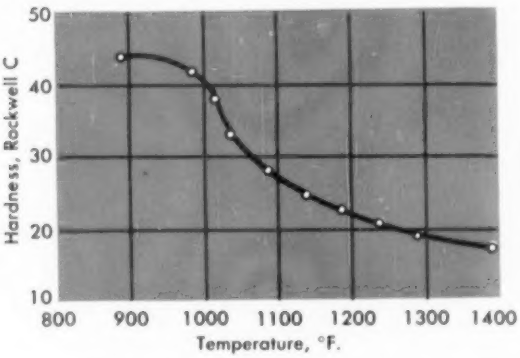


Fig. 1 – This Graph Illustrates the Sudden Drop in Hardness Which Occurs When Quenched Type 410 Is Tempered Above 980° F. A hardness of Rockwell C-35 is generally desired in the final product

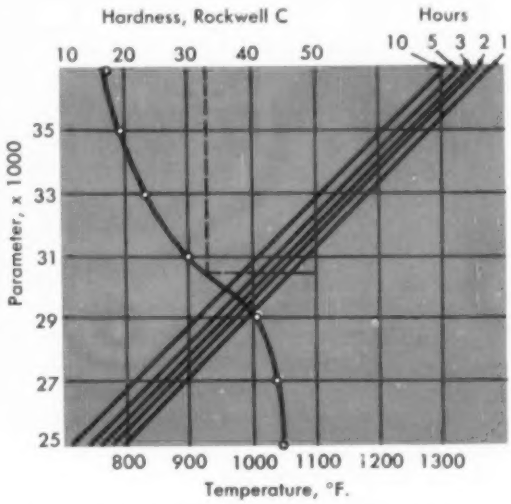


Fig. 2 – Graph of Time-Temperature Curves and Parameter Curve. The dotted lines show that the same hardness can be achieved by several combinations of time and temperature

catalogs, and personal observation in our own plant to replot a chart more suitable for shop use (see Fig. 2).

Both equations are drawn on the same sheet. That for the time-temperature relationship is exact, having been computed for various values of T and t. The hardness-parameter function (which is based on an as-quenched hardness of C-44) is then superimposed in such a manner as to give a simultaneous solution for combinations of time, temperature and hardness. The parameter scale shown in the chart is used only for construction and does not appear on the shop chart.

The dotted line gives an idea of how the chart is used. Any horizontal on the chart is an iso-parameter level; its intersection with the diagonal time-temperature lines will give combinations of time and temperature which satisfy the hardness requirements. The experienced heat treater will know, after examination of the part, about how long it should be tempered (2 hr. per in. of thickest section is good), and this, in turn, will fix the temperature to be used. We also designate 2 hr. as the minimum tempering time for any section.

Should the as-quenched hardness be materially different from Rockwell C-44, imagine a line parallel to the hardness-parameter curve offset in the appropriate direction by the amount of the difference. Time and temperature are then determined by the "new" line.

In practice, we have found that normal variation in chemical analysis creates a hardness band which varies about one or two points to either side of the curve. In statistical terms, this constitutes a two-sigma band about the mean and, as such, should contain about 90 to 95% of the individual observations. This has been borne out with continued use. Some nine times out of ten the observed hardness after using the chart will not be off more than one or two points in one direction or the other.

Furthermore, where a range of final hardness is specified, it is well to use the chart toward the upper bound, and to use the lower temperatures with the longer times. It must be remembered that the time (t) is time-at-temperature, and one of the major problems is that of estimating the time needed to bring the charge up to temperature. The effect of this inaccuracy is minimized by using the longer times. Then, too, if the charge contains several pieces, the operator can remove one piece to check his progress and return it to the furnace without materially affecting the rest of the charge.

Summary

We have found the Hollomon-Jaffe tempering parameter to be very useful in tempering Type 410 stainless steel in those ranges where the hardness drops rapidly with a rise in temperature. Published data supplemented by shop observation have been treated statistically to arrive at a curve relating final hardness and the parameter $T(20+\log_{10}t)$. This, in turn, is superimposed on curves relating the parameter with time and temperature so as to arrive at a simultaneous solution of the parametric equations for the hardness required.

Babbitting Bearings by Centrifugal Force

*By W. B. KEYSER**

Babbitt is a commonly used bearing material for high-speed service. Its only serious handicap is its low strength. This disadvantage is overcome by bonding a thin layer of babbitt to a strong backing material. An improved centrifugal casting method results in a more uniform structure in the bearing metal. (E14; Sn, SGA-c)

THE MAINTENANCE SHOPS of a gaseous diffusion plant are assigned a variety of jobs. Recently, for example, the shops at Goodyear Atomic Corp. were requested to babbitt the bearings used in high-speed centrifugal compressors. For high-speed service, babbitt is in general the most satisfactory bearing material. Its only serious handicap is its load strength. Analyses of some typical tin-base babbitts are as follows:†

	S.A.E. NUMBER		
	10	11	12
Tin	90% min.	86%	87.75%
Lead	0.35 max.	0.35	0.35
Antimony	4-5	6-7.5	7-8.5
Copper	4-5	5-6.5	2.25-3.75
Arsenic	0.10 max.	0.10	0.10

Thick layers of babbitt can be displaced under heavy loads. To overcome this drawback, the babbitt is generally bonded to a strong backing material and machined to a thickness of 0.001 to 0.003 in. Generally speaking, increased loads are accommodated by decreasing the thickness of the white metal.

There are several ways of bonding the babbitt metal to the backing material. These include shell casting and centrifugal casting. Shell casting involves a number of control problems and objectionable defects (porosity and lack of bonding), so centrifugal casting techniques were investigated and have been successfully adopted.

The backing material, leaded bronze (nominal composition 85% Cu, 9% Pb, 5% Sn, 1% Zn), was cleaned preparatory to bonding. In this process a fine machine cut was followed by a degreasing treatment. The bushing was then fluxed with a 25 to 40% aqueous solution of a proprietary compound known as "Tin-Kwik" to remove the oxide film from the bushing surface. The bushing was then heated to 500° F. on a hot plate and tinned with babbitt alloy by scratch brushing.

A 16-in. lathe was used for centrifugal casting. Disks were clamped over the ends of the bushing to prevent the escape of liquid babbitt, and a

Fig. 1 – Bronze Bushing Babbitted by Shell Casting. Bonding is incomplete and the babbitt metal is punctured with porosity and blowholes

*Technical Dept., Goodyear Atomic Corp., Portsmouth, Ohio. This work was performed under contract At-(33-2)-1 with the U. S. Atomic Energy Commission.

†From "Sleeve Bearing Materials," by R. W. Dayton and others. Published by American Society for Metals, 1949, p. 16.

Fig. 2 – Pouring Measured Quantity of Babbitt Metal Into the Bushing for Centrifugal Casting

special jig held the assembly in the lathe. The babbitt was poured into the bushing through holes in the disks.

The babbitt material was melted, held at 550° F. and fluxed with Tin-Kwik. The dross was then skimmed off the melt. As the lathe turned slowly, a small amount of flux was poured into the bushing. Then the bushing was heated by an oxy-acetylene torch to 550° F. Since the bushing temperature appeared to be critical, the lathe was stopped from time to time so that the temperature could be measured with thermocouples. After the desired temperature was attained, the lathe speed was increased to 1000 rpm. and a measured quantity of babbitt was poured into the bushing, resulting in a layer 0.125 in. thick (Fig. 2). At this speed, all porosity was eliminated and all dross was forced to the surface.

The assembly was then cooled by a water spray directed toward the outside of the revolving cylinder to promote directional freezing. Finally, the bearing was finished by machining. Figure 3 shows a well-bonded, porosity-free babbitt applied to a bronze bearing by centrifugal casting. The importance of correct bushing temperature is shown in Fig. 4 and 5. If the bushing is too cold, the bond is poor; if the temperature is too high, some alloying occurs.

Fig. 3 – Cross Section of the Centrifugally Cast Babbitt-Bronze Interface. A solid bond free of porosity is obtained. Babbitt metal at top. 125×

Fig. 4 – Control of Bushing Temperature Is Important. Incomplete bonding results when bushing is too cold (450° F. in this example)

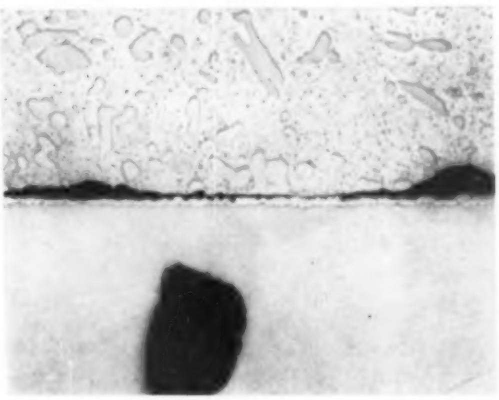
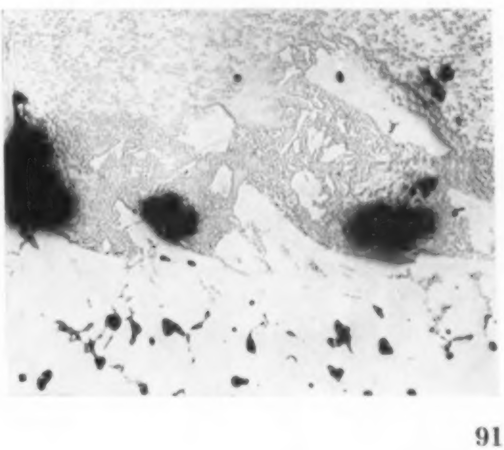


Fig. 5 – Overheating the Bushing (700° F.) Causes It to Alloy With the Babbitt. (25 ×)



Hazards From Fall-Out

[A committee of scientists from Argentina, Australia, Belgium, Brazil, Canada, Czechoslovakia, Egypt, France, Great Britain, India, Japan, Mexico, Sweden, United States and U.S.S.R. was appointed in 1955 by the United Nations General Assembly to study and report on the effects of atomic radiation on human beings. The "General Conclusions" in a report submitted Aug. 11, 1958, are quoted in the right-hand column below. At left is a version of the first paragraph submitted by Russia and Czechoslovakia. On the page at right is still a third view.]

Stop Testing Immediately
(The Russian View)

[Apparently the only difference of opinion was in the wording of the first paragraph of the "General Conclusions." The Russian, Czechoslovakian and Egyptian representatives favored the following, but it was rejected by the majority—as was reported in the *New York Times*—on the ground that the last sentence involved political considerations outside the scope of the committee.]

The scientific information received by the committee indicates that the genetic effects of radiation must be considered reactions for which there is no threshold. This means that any increase in the exposure of the human organism to radiation will lead to an increase in the incidence of hereditary diseases. According to one body of scientific opinion, malignant neoplasms and also leukemias are diseases the incidence of which may increase as the level of radiation rises. These data, together with the fact that there is very little likelihood that the human organism can adapt itself to conditions of increased environmental radiation, indicate that any increase in the radiation dose above the natural radiation level must be considered undesirable for mankind. Efforts should accordingly be made to improve the physical basis and the technique of the medical use of radiation by formulating more precise indications for the use of radiation and by eliminating adverse side effects. It is also essential to develop, on the basis of broad international cooperation among scientists, research on the improvement of protection and safety techniques in atomic industry and in science and technology. The physical and biological data presented in the report make it plain that efforts should be made to eliminate the uncontrolled source of radiation, that is, to end experimental nuclear and thermonuclear explosions, and enable the committee to draw the conclusion that there should be an immediate cessation of test explosions of nuclear weapons.

General Conclusions
(The Majority View)

The exposure of mankind to ionizing radiation at present arises mainly from natural sources, from medical and industrial procedures, and from environmental contamination due to nuclear explosions. The industrial, research and medical applications expose only part of the population while natural sources and environmental sources expose the whole population. The artificial sources to which man is exposed during his work in industry and in scientific research are of value in science and technology. Their use is controllable, and exposures can be reduced by perfecting protection and safety techniques. All applications of X-rays and radioactive isotopes used in medicine for diagnostic purposes and for radiation therapy are for the benefit of mankind and can be controlled. Radioactive contamination of the environment resulting from explosions of nuclear weapons constitutes a growing increment to world-wide radiation levels. This involves new and largely unknown hazards to present and future populations; these hazards, by their very nature, are beyond the control of the exposed persons. The committee concludes that all steps designed to minimize irradiation of human populations will act to the benefit of human health. Such steps include the avoidance of unnecessary exposure resulting from medical, industrial and other procedures for peaceful uses on the one hand and the cessation of contamination of the environment by explosions of nuclear weapons on the other. The committee is aware that considerations involving effective control of all these sources of radiation involve national and international decisions which lie outside the scope of its work.

Certain general conclusions emerge clearly from the foregoing part of this report:

1. Even the smallest amounts of radiation are liable to cause deleterious genetic, and perhaps also somatic [bodily] effects.

2. Both natural radiation and radiation from fall-

out involve the whole world population to a greater or lesser extent, whereas only a fraction of the population receive medical or occupational exposure. However, the irradiation of any groups of people, before and during the reproductive age, will contribute genetic effects to whole populations in so far as the gonads are exposed.

3. Because of the delay with which the somatic effects of radiation may appear, and with which its genetic effects may be manifested, the full extent of the damage is not immediately apparent. It is, therefore, important to consider the speed with which levels of exposure could be altered by human action.

It is clear that medical and occupational exposures, and the testing of nuclear weapons, can be influenced by human action, and that natural radiation and the fall-out of radioactive material already injected into the stratosphere cannot.

Progress Involves Risk
(The A. E. C. View)

[In September 1955, about the time the U.N. Committee was formed, the late John von Neumann, then member of the U.S. Atomic Energy Commission, wrote the following memorandum.]

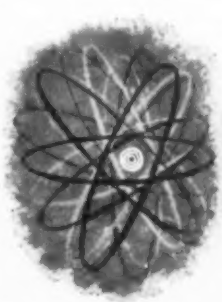
This is a restatement of the remarks that I made regarding the probable consequences of a United Nations' sponsored study of world-wide radiation effects.

I think that such a study is, in the long run, neither undesirable nor avoidable *per se*, but it contains considerable elements of danger, unless certain points that we must insist on are understood *a priori*. If these points are not appreciated, the study would be worse than a good deal of international unpopularity.

The points that I have in mind are the following ones:

The present vague fears and vague talk regarding the adverse world-wide effects of general radioactive contamination are all geared to the concept that any general damage to life must be excluded, and at that with certainty. However, it is quite certain that no realistic and operable approach to these problems will be found, until and unless it is realized that this approach is absurd.

History shows that no industry, no human effort, no progress has ever been achieved on such terms. Every worthwhile activity has a price, both in terms of certain damage and of potential damage – of risks – and the only relevant question is whether the price is worth paying.



No progress in medicine was ever achieved without incurring physiological and biological risks, sometimes of even only very vaguely foreseeable orders of magnitude. The history of the introduction of X-rays is an eloquent example of this, and no one can tell whether our present practices with antibiotics and hormones may not repeat some phases of that experience.

The chemical industry has affected local climate in some important cases in unforeseen – and sometimes still unexplained – ways. Every industry, every new means of transportation, imposes its quota in casualties and fatalities.

It is characteristic that we willingly pay at the rate of 30,000 to 40,000 additional fatalities per year – about 2% of our total death rate! – for the advantages of high-speed individual transportation by automobile.

It is also characteristic that the safety standards of the nuclear industry are a good deal higher than those of the established industries. Two examples will illustrate this:

All our Pacific tests had casualties – all, except the "Castle" fall-outs, were due to non-nuclear activities, like automobile accidents, accidents involving the operation of ships, etc. The "Castle" fall-out had one fatality and endangered to varying degrees about 200 people; within a few weeks of it the capsizing of a ferry in northern Japan, in the course of its normal operation, killed about a thousand people, including twenty Americans – yet the "Castle" fall-out was what attracted world-wide attention.

The really relevant point is: Is the price worth paying? For the United States, it is. For another country, with no nuclear industry and a neutralistic attitude in world politics, it may not be. In a United Nations discussion we must not concede ahead of time that we may not concur with other countries' evaluations in this regard. The evaluation itself may involve questions of national interest, and ours may differ from that of other countries.

This is particularly true, since the majority of the United Nations countries is in fact not productive in the atomic energy industry, and any proposal designed to minimize, to eliminate dangers, risks, etc., will be *per se*, popular with them.

A certain amount of international unpopularity is therefore unavoidable for us, and we will have to accept it as part payment for our more advanced industrial position.

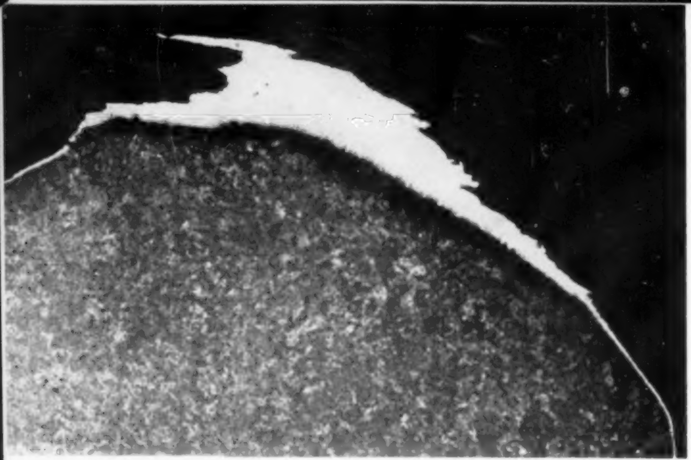


Fig. 1 – Untempered Martensite Produced in Hammer Head by Heavy Blow. The dark zone below the white martensite has been tempered by localized heating

Producing Martensite by Impact

*By H. O. McINTIRE and G. K. MANNING**

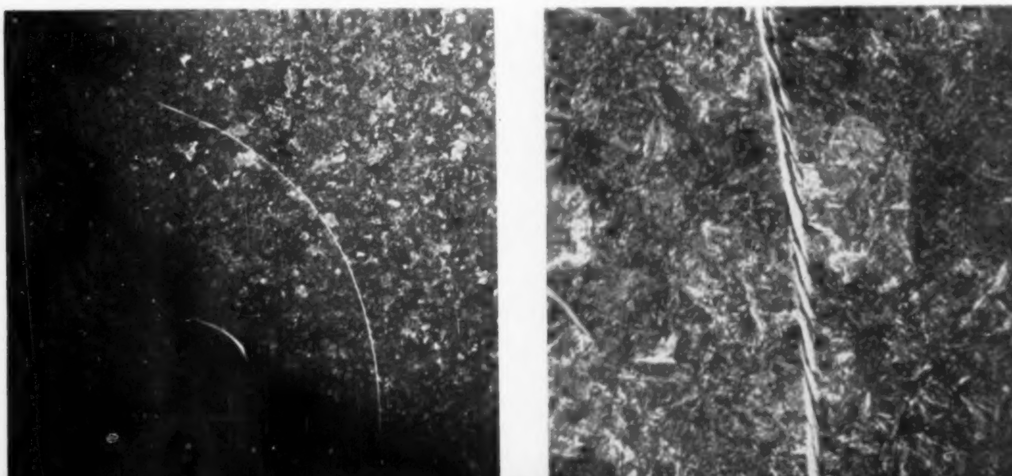
Sharp blows can produce hard, brittle martensite in hammer heads when edges break off. The use of chipped hammers is discouraged. (A7p, Q29n, Q26s; ST)

SHOP SAFETY RULES generally include the information that "all hammers whose heads are chipped should be immediately discarded". The usual reason is that any such hammer is likely to chip again because sharp edges break off easily. While this is true, there is a special reason for a chipped hammer's fragility. Martensite can be formed by sharp impact. This martensite, being untempered, is quite brittle and further spalling may occur with little effort.

Our work began with the study of microstructures of hammers spalled in service. We examined the spalled surfaces and found a thin layer which remained white after polished sections were etched with 4% picral. In addition, sections through these areas frequently revealed segments, smaller than the main chip and still intact, which were almost completely outlined by thin bands of the white material. This zone was very hard – Rockwell C-67 to 68. In the 0.8% carbon steel, from which the hammers were made, this hardness could only be attained by a structure consisting mainly of untempered martensite. Figure 1 illustrates this white zone; immediately beneath this zone of high hardness lies a softer region (Rockwell C-51 to 53) which grades into the normal hardness of the hammer of about Rockwell C-58 to 59. The softer intermediate zone is highly tempered martensite – evidence of localized heating. The explanation is that the hard layer must have been heated above the austenite transformation temperature;

*Assistant Chief and Division Chief, respectively, Metallurgical Engineering Div., Battelle Memorial Institute, Columbus, Ohio.

Fig. 2 – Untempered Martensite Outlines a Fragment in the Left Micro (50 ×). This small piece is ready to break off; partial fracturing is evident in the enlarged section at right (500 ×)



it was then quenched by the cold metal adjacent to it. The softer intermediate zone was heated close to, but did not exceed, the transformation temperature.

Supplemental X-ray data also revealed an appreciable amount of austenite in the hard layer. Since the adjacent material contained no measurable amount of austenite, this is further evidence that the hard zone was heated above the austenite transformation temperature by the shear-strain energy, and very rapidly quenched.

An instance where only partial spalling occurred is illustrated in Fig. 2. Untempered martensite outlines a particle which has nearly, but not quite, broken away. A hammer in this condition is a very dangerous tool; the next blow can easily dislodge the fragment.

In conclusion, it is apparent that lines of untempered martensite are produced in hand hammers in service. Safety engineers know what they are talking about when they object to use of chipped hammers.

Book Review

Tables of Crystal Structures

Reviewed by CHARLES S. BARRETT*

A HANDBOOK OF LATTICE SPACINGS AND STRUCTURES OF METALS AND ALLOYS, by W. B. Pearson, Pergamon Press, New York, 1958. 1044 p. 221 fig. $38.

ANYONE who has done X-ray work on metals must have had this experience: His colleagues would continually ask him for the lattice constants of some solid solution or other, or the crystal structure of some intermetallic phase. There was a time when these could be quite annoying questions – the answer was hidden somewhere in several thousand volumes of the scientific journals. Then the famous old series of abstracts, *Strukturbericht*, was brought up to date in *Structure Reports*, published under the auspices of the International Union of Crystallography. One could then suggest that he look through all 15 of these volumes and find all the structure determinations that have been done – which would send him off grumbling that there ought to be an easier way.

Then, in 1950, some help arrived. A graduate student in physics at Case, K. Polmanteer (with help from his wife) undertook to assemble the data on lattice parameters versus composition for binary metallic solid solutions. This resulted in a Master's degree thesis which, even though it had a strictly limited scope and was prepared by a relatively inexperienced team, became a valued possession of those few of us who were fortunate enough to be given a copy.

The great convenience of having a large collection of related data in one volume has made me keenly appreciate the efforts of anyone who undertakes any part of this kind of summarizing. And there are tables that appear from time to time. For instance, the Metals Handbook has X-ray data of this sort, though it makes no pretense of complete coverage of either binary or ternary alloys; and C. J. Smithell's Metals Reference Book has 45 pages of good crystal tables that must have helped many a man, though they do not include the variation of unit cell dimensions with varying composition.

But there has been no attempt to collect in one volume all the best data for all the binary, ternary and quarternary metallic systems and the pure metals. I personally had given up hope that this would ever happen – that a man existed who could find the time, patience, and enthusiasm to undertake the task, and at the same time have the knowledge and judgment required to do a first-class job of it. But there is such a man, and I heartily recommend that he be given all

*Professor, Institute for the Study of Metals, University of Chicago.

thanks and respect, and that the organization supporting the man, the National Research Council at Ottawa, Canada, be given due credit.

The man who undertook the task is W. B. Pearson, a well-known physical metallurgist and crystallographer who has published original research of high merit in research journals for many years, and who is now one of the editors of *Structure Reports*.

The first 75 pages of Pearson's impressive book are devoted to discussion of various matters related to the main tables. After a careful explanation of the wave lengths and units used by experimentalists now and at various times in the past, and a listing of the methods used to obtain high precision in lattice spacing measurements, there is a concise but competent discussion of X-ray methods of determining phase boundaries in binary and ternary phase diagrams. This is followed by a chapter on the empirical relations that have been found by the Oxford and German schools between the crystal structure and lattice spacings of alloy phases and the following parameters: electron concentration, size factor, relative valency factor, and electrochemical factor.

There are many who will appreciate the neat, concise summary of these empirical rules, but there are also some who will note that they are fully treated in various other books and journals and could have been omitted here in favor of a less expensive book containing little more than the tables of greatest value. In addition, some will cringe a bit at the detail with which the author explains the interpretation of these empirical rules in terms of Fermi surfaces and Brillouin-zone boundaries, when it begins to be apparent that modern solid-state physicists at Cambridge, Chicago and many other universities are steadily and rapidly revising our concepts of what Fermi surfaces *really* are like in metals and also in alloys. Long before the main tables in the book have become too out-of-date to be of value, the author will doubtless wish he could revise various details in this theoretical section.

There should be permanent worth in the remaining portions in the introductory section—the relationships that are found between lattice spacings and ferromagnetism, antiferromagnetism, paramagnetism, quenching stress, particle size, superlattice order, superconductivity transition temperature, and measured densities. Here the discussion is limited to the empirical facts.

In the main tables of the book, the crystal structures are referred to with the *structurbericht* type number when this has been possible. This need not dismay those who are relatively unfamiliar with this arbitrary system of symbols, since a full list is included in a table which also gives the coordinates for each atom in the unit cell, a statement of the position of the origin of coordinates with respect to the symmetry elements of the structure, the number of atoms or molecules in the structure, the symmetry elements and space group, and the coordination number for each kind of atom in the unit cell. While drawings of the structures are not included, they can readily be made from the data given if the reader understands the notation now universally used for atoms in a set of "equivalent positions" in the unit cell.

One table covers the metallic elements, giving crystal structures (including atomic parameters and space group), density, coordination number, interatomic distances, the temperature of determination and, as an extra dividend, the linear expansion coefficients. Another table covers the intermediate phases of binary and multicomponent metal systems (in this instance without temperatures and expansion coefficients), and another table covers similar data for borides, carbides, hydrides, nitrides and binary oxides.

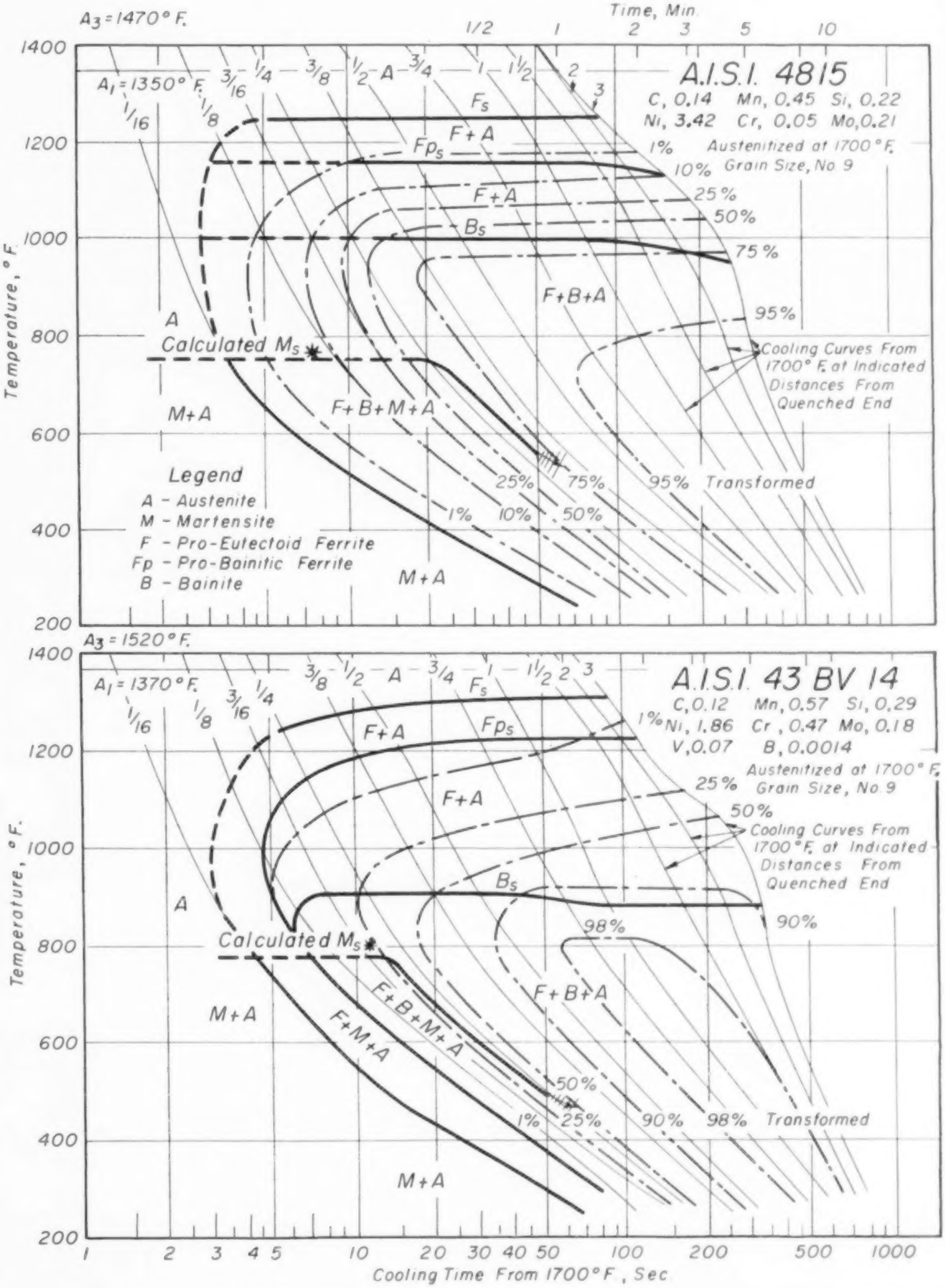
The remaining tabulation (784 pages' worth) contains summaries of the best determinations of structure type and lattice constants for metals and for binary and multicomponent alloy equilibrium phases. Variations of lattice spacings with composition and with temperature are given. The arrangement is alphabetical by elements present in each alloy system.

Pearson has carefully included references to the publications from which he obtained his data, but has not referred to publications that he finds have been superseded by better work; thus he has included only data that in his judgment represent the best information obtainable. By reading the references cited, however, it is possible for the reader to find the earlier papers.

When a work as carefully planned as this is carried out by a man of outstanding judgment and skill, there is only one major question left to answer: Is it reasonably complete in coverage? Considering the sources that were referred to and the cross-checking that was done, as described in the preface to the book, the coverage could hardly be otherwise, especially from 1936 through 1955. I am pleased to report that a liberal sampling and checking of the data indicates that the quality is extremely high, both as to completeness of coverage and accuracy. The book can be relied upon.

Cooling Transformation Diagrams for A.I.S.I. 4815 and 43BV14

By R. C. Hess and E. Kozic, Research Dept., Bethlehem Steel Co.



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Staff Report

How to Make More Steel

Blast furnace improvements, bigger electric furnaces, and more rolling mills have added 500,000 tons to the annual capacity of the Republic Steel Corp. plant in Chicago. This 40% increase was achieved without adding more melting equipment.
(D1, D5, F23, 1-52; ST)

THE SOUTH CHICAGO PLANT of Republic Steel Corp. has for the past two years been increasing its steelmaking capacity. This is not unusual because other steelmakers have been doing it too. However, Republic is adding to its capacity in an unusual way – without adding to the number of melting furnaces. With the job done and the capacity at 1,700,000 tons yearly, the plant still has one blast furnace, four openhearths, and nine electric furnaces. It had this number when the plant was completed in 1951.

Preliminaries

While the recent expansion began in 1955, the real story starts with the construction of the defense plant during World War II. At that time, the South Chicago mill included eight stationary openhearths (which could only be operated with cold metal), some old rolling equipment, and a modern wire mill. Since the full story of the wartime additions is told elsewhere*, we will merely list the additions made then. They included one pressure-top blast furnace which could make 1300 tons of pig iron daily, four tilting openhearths, nine electric furnaces, and a rolling mill capable of processing most of the steel produced by both the old and new melt shops. Auxiliary equipment for the blast furnace included ore docks, a sinter plant, and byproduct coke ovens.

*See "Plancor 422 – A Wartime Steel Plant", *Metal Progress*, February 1955, p. 109.

Steel was produced in great tonnage until business fell off in 1948. Since the stationary openhearth shop was antiquated, expensive to operate, and could not be adapted for hot metal use, it was taken out of production. The old 35-in. blooming mill was also shut down since the newer 44-in. blooming mill could now roll far more steel than it was getting from the wartime melting furnaces still in operation. This situation continued until 1953 when a seamless tube mill, capable of 276,000 tons annually, was built. Since this added to the already copious rolling capacity, more steel became essential. Production was increased by various expedients (such as melting 85 tons in the 70-ton capacity electric furnaces, and making 300-ton double-ladle heats in the openhearths), but it was evident that more permanent arrangements were needed. Yet, space and cost problems were unreasonable for the addition of more melting furnaces. The ingenious plans formulated and carried through by Republic to solve this dilemma make this an interesting industrial saga.

Blast Furnace

To begin with, adding 500,000 tons to a 1,200,000-ton capacity plant takes a lot of hot metal and pig iron. Yet – to put it bluntly – new blast furnaces cost too much. Consequently, the only practical answer was to increase the capacity of the one blast furnace available. (For many years the furnace produced between 1300

Fig. 1 – Charging a Top-Charge Electric Furnace. The top is raised and swung aside to permit lowering and emptying of the bucket. The three 135-ton electric furnaces have similar arrangements

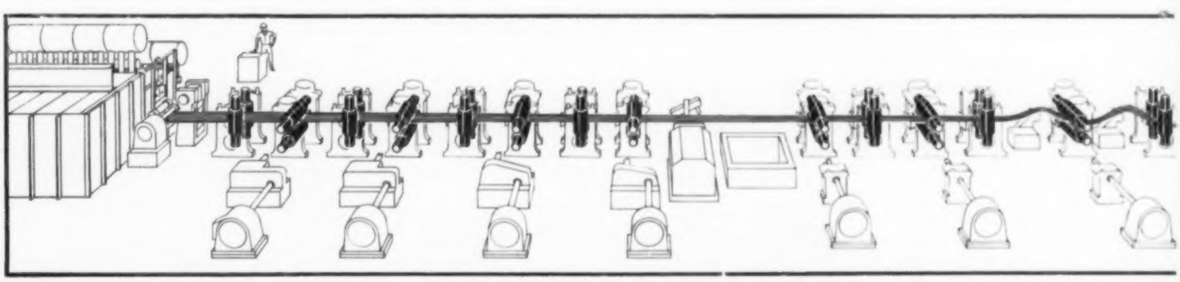
and 1400 tons daily.) This was done by installing a new 110,000-cu.ft. per min. blower. After relining and other repairs, furnace production increased to a rated 1625 tons daily. In fact, latest production figures show it has risen to 2000 tons per day. Where is this extra hot metal going? To electric furnaces and openhearths, of course.

However, more furnaces could not be built because space was not available. The solution was to enlarge electric furnaces already existing. At first, top charging was tried. By altering the roof so that it could be swung to the side, it was possible to load all the necessary scrap in one operation from large crane-carried buckets as Fig. 1 shows. The two furnaces converted for top charging were able to make a 70-ton low-carbon rimming heat in 5 hr. from charge to tap.

Later, three more furnaces were replaced by 135-ton units. These are all charged through the top, and have, at times, made heats as high as 150 tons. Naturally, larger ladles (and stronger crane runways) were needed to accommodate these larger heats. Another soaking pit crane was also added.

Rolling Capacity

As stated before, the 44-in. mill through which all ingots are bloomed could easily accommodate the added melting capacity. This was not true for the 36-in. mill which produced smaller billets and rounds for the 21-in., 12-in., and 10-in. bar mills, the seamless tube mill, and for outside



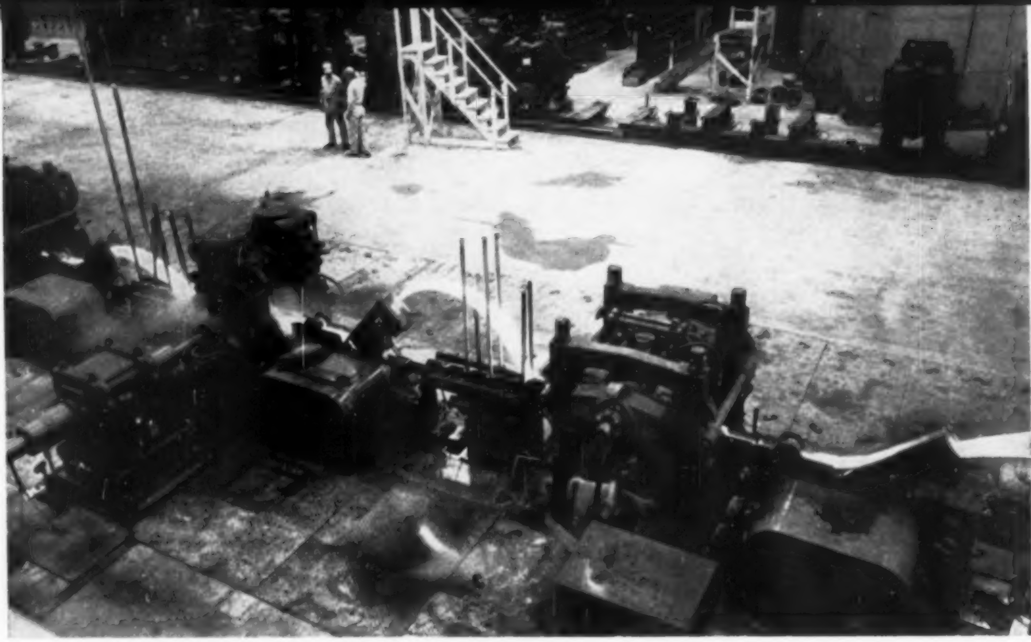


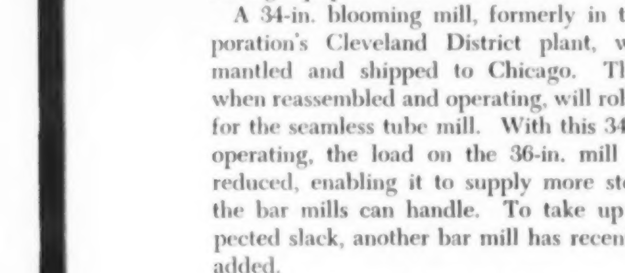
Fig. 3 – Flats Being Rolled in New Bar Mill. Looping feature permits synchronization of the rolls

sale. With the extra capacity, more auxiliary rolling equipment was needed.

A 34-in. blooming mill, formerly in the Corporation's Cleveland District plant, was dismantled and shipped to Chicago. This mill, when reassembled and operating, will roll rounds for the seamless tube mill. With this 34-in. mill operating, the load on the 36-in. mill will be reduced, enabling it to supply more steel than the bar mills can handle. To take up the expected slack, another bar mill has recently been added.

This mill, capable of rolling ⅜ to 1¼-in. rounds, squares, hexagons, and special sections, as well as concrete reinforcing bars and 1 to 4-in. flats, has been installed between the 10 and 12-in. mills. (This location makes additional maintenance facilities unnecessary.) Incorporating many new features, the mill produces up to 85 tons every hour with only six men operating the controls. A diagram of the mill is shown in Fig. 2. The alternating horizontal and vertical rolls exert equal pressures around the bar without twisting between stands. Close tolerances are possible. A unique feature of this mill is the vertical looping illustrated by Fig. 3. This is as necessary in operation as it is spectacular in appearance. As the billet passes through each set of rolls, its size is reduced and its length increased. Upon reaching the last few stands, its speed on leaving one stand is greater than the speed at which it can enter the following stand, and it has to be slowed or looped to keep it from piling up between stands. When stand speeds are synchronized, looping is stabilized as shown in the photograph. The bar leaves the final stand at 3000 ft. per min. Each of the 16 individually driven mill stands is controlled from a central panel enabling adjustment of the speed of each stand separately. This is one of the most modern bar mills in operation today.

Fig. 2 – Diagram of 11-In. "Straightway" Bar Mill. The alternate vertical and horizontal rolls and the looping feature are two innovations in this modern mill. Six operators can roll up to 100 tons daily



Wire mill capacity has also been increased 50% by the addition of 15 wiredrawing machines, 22 nail-making machines, annealing, tempering and pickling facilities, and a new warehouse.

Summary

With these additions, Republic will be in a good position for the future. The added equipment has been fitted into existing capacity so that full use can be made of *all* equipment. Clever planning has made more melting furnaces unnecessary. When we consider that the capacity has been increased by 40%, this is a noteworthy achievement.

Quality Control in Specialty Steel Production

By J. S. PENDLETON, Jr.
*and H. O. BEAVER, Jr.**

Four factors – scrap, composition, temperature and design – influence ingot quality. Control of these variables produces ingots with consistent properties from heat to heat. (D9, N12b; ST, 5-59, 9-69)

A MAJOR SOURCE of difference in performance between batches of steel with the same nominal composition and mechanical properties is the structural variation between surface and core metal in the ingot. This variation is caused by differences in freezing rates between surface and center; while the rapidly freezing surface zone will usually be solid and homogeneous, the center, which solidifies more slowly, may contain porosity and segregated impurities.

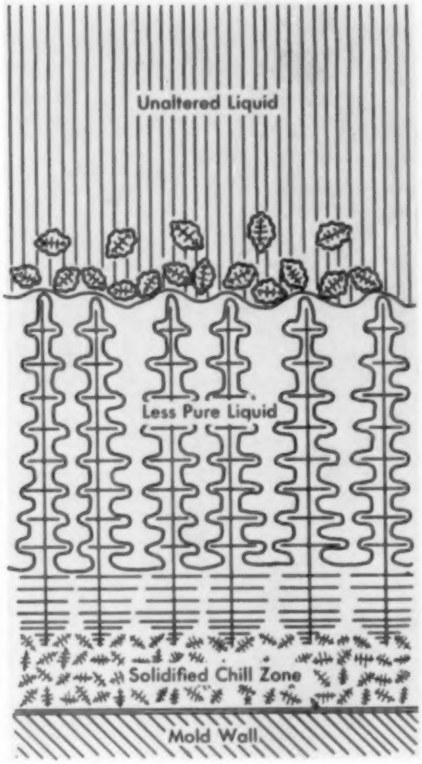
Bars made from badly segregated ingots can be detected and scrapped by routine quality controls such as macro-etching or ultrasonic inspection. Unfortunately, not all dangerous segregation is found even with the most rigid standard controls. This undetectable segregation is one of the major causes of variation in tool performance.

All steelmakers have trouble casting a homogeneous ingot that is essentially free of segregation or porosity. Ideally, the steel ingot should be uniform from top to bottom and center to surface in both analysis and structure. We at Carpenter Steel Co. have been working on the problem for some time and believe we have made progress. Careful control of scrap, melt composition and bath temperature, plus our patented ingot mold, help us to produce specialty steels with more consistent properties from heat to heat.

*Metallurgists, Carpenter Steel Co., Reading, Pa.

To review the problem, deoxidized steels are usually poured in big-end-up cast iron molds with an insulating hot top. When the metal is poured into the mold, solidification starts at the mold wall surface. The metal in contact with the mold surface chills rapidly, freezing in small, randomly oriented crystals. This zone is called the "chill" zone and has very little segregation. Its thickness varies little with different steel compositions and its effect on solidification depends upon the thermal conductivity of the particular analysis.

Immediately adjacent to this chill zone is a region where the steel solidifies into long columnar crystals (consisting of interlocking dendrites) oriented nearly perpendicular to the mold wall but sometimes inclined slightly upward. As these crystals grow, the temperature of the remaining molten metal decreases to a point where



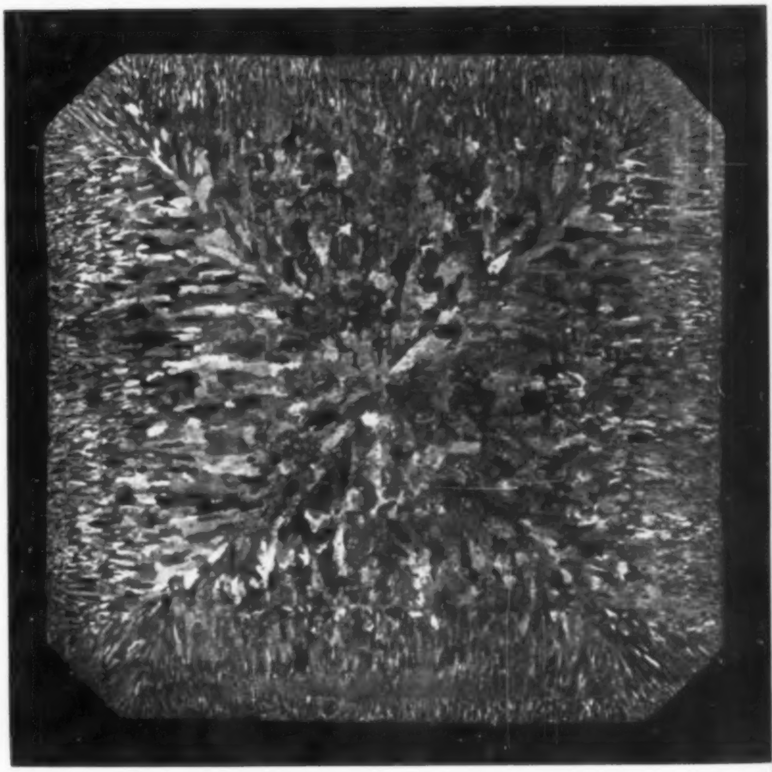


Fig. 1 – Diagram Showing Formation of Chill and Columnar Zones During Ingot Solidification. The chill zone forms rapidly at the mold wall; as the freezing rate slows, dendrites extend into the melt. The photograph illustrates a typical solidification pattern

small crystals start to grow in the center of the ingot body. These small crystals precipitate additional solidification and hinder growth of columnar crystals. As a result, the center of the ingot consists of equiaxed crystals. The three different zones of solidification – chill, columnar crystals and equiaxed crystals – are apparent in all steel ingots. However, their size and location vary according to alloying elements, pouring temperature, pouring rate and ingot mold design.

Solidification Mechanism

Alloying elements (or impurities) lower the temperature at which solidification starts. High-purity metal freezes first and the remaining molten metal has a higher freezing temperature because of the alloying elements and impurities. As solidification progresses, impurities are concentrated in the molten metal. Some of this lower purity metal is trapped between the growing dendrites and freezes so that, alternately, there are "layers" of different purity levels. However, much of the less pure molten metal is continually pushed toward the center so solidification progresses from the bottom and the sides of the mold. The mechanism of the crystal growth and the resulting pattern are shown in Fig. 1.

The impure metal pushed to the ingot center contains small frozen crystals. Since these are denser than the molten metal, they sink to the mold bottom. This results in a zone of reduced alloy content in the lower section of the mold called a "zone of negative segregation". "Zones of positive segregation" develop toward the top as solidification continues. The resultant segregation patterns, highly simplified, are shown in Fig. 2.

If solidification at the top and bottom of the mold continues at the same rate, eventually molten metal from the top will not be able to fill the cavity created by shrinking of the freezing metal, and pipe or porosity can result.

Many of the problems imposed by segregation can be minimized by our new mold. This mold

(Fig. 3) is designed to extract heat rapidly at the bottom of the ingot. Short, stubby molds are placed on a heavy copper stool inserted in a cast iron mold that promotes solidification from the bottom up. This traps impurities in the top, which can then be cut off and discarded. There is an essential relationship between the height (or axial length) of the mold cavity to the width at the top of the cavity. Height-to-width ratio should be between 2 and 2.6. The ratio of mold wall area to the cross-section area is also important; it should range from 0.50 to 0.70 at the top, and from 2.40 to 2.70 at the bottom. Mold taper is between 0.6 and 1.0 in. per ft.

Other Quality Methods

Ingot design alone cannot eliminate segregation. Poor quality ingots can be produced in the new mold unless all other variables that influence ingot quality are properly controlled. Here, three major variables (other than the patented ingot mold) are used to control ingot quality. They are scrap control, composition control and temperature control.

Scrap control is important not only for its effect on core quality but also because of the adverse effect of residual elements. Since World War II, for example, the average molybdenum and copper content of stainless scrap has doubled because neither element is oxidized in melting. As both elements decrease the forgeability of stainless steels, the scrap charge of heats for forge stock must be segregated to assure predictable performance. The alloy used for steam turbine blading (A.I.S.I. Type 403, a low-carbon 12% chromium alloy) is a good example of critical forging requirements. For the best forging quality and closest control of mechanical properties from our billets, we have found it necessary to segregate scrap for this grade into *six* different categories within tight composition limits so that the furnace charge will contain a minimum amount of harmful residuals. Adequate inspection of incoming lots requires 75 to 80 samples for proper control.

Residual elements (such as nickel, cobalt and columbium) in high speed steels can cause erratic response to heat treatment. Our scrap specifications for these steels are extremely narrow; to assure uniformity, we require at least

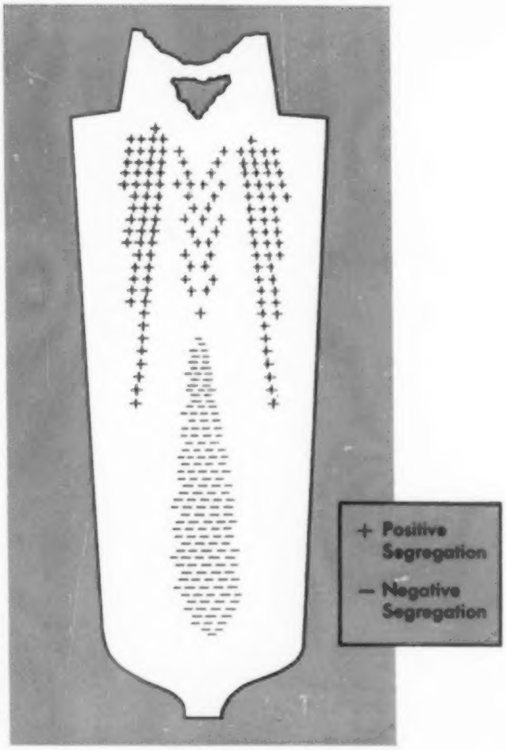


Fig. 2 – Typical Segregation Pattern of Solidified Ingot. Where segregation is "positive", alloy and impurity content are higher than the nominal composition

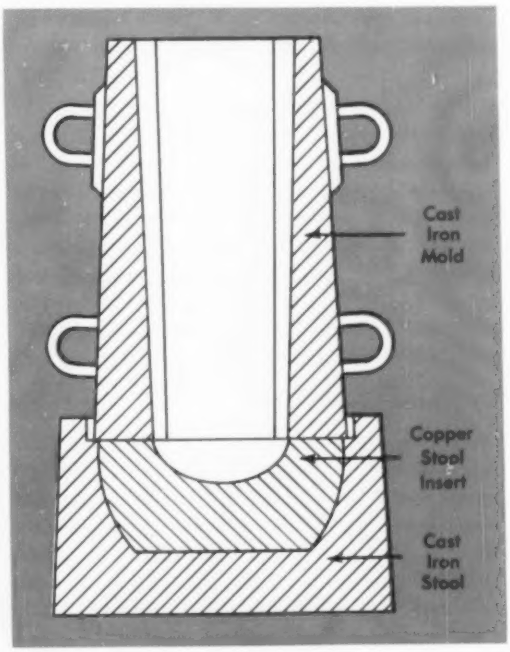


Fig. 3 – Diagram of New Mold. The massive copper stool extracts heat rapidly, and this promotes freezing from the bottom up. Impurities are trapped at the top

six sample analyses per ton of scrap charged.

For tool and die steel, a sizable portion of the scrap originates in machining departments and often is coated with small amounts of oily cutting compounds. To eliminate these, scrap is usually burned before charging into the furnace. Lead and tin in some cutting compounds can cause "hot shortness" in stainless and high-temperature alloys. Scrap contaminated by such impurities must be avoided.

Composition control during melting is essential; while the heat is molten, its composition is continually changing. Elements which oxidize readily (carbon, chromium and manganese) react with slag and oxygen; amount of each remaining is a function of both time and temperature.

At Carpenter Steel Co., variation in composition is reduced to a minimum by frequent spectroscopic analysis of the heat. All major elements can be determined within 3 min., and the amount of any important minor element in less than 12 min. Such rapid analysis permits thorough control of composition throughout the melting cycle.

Temperature control of the molten steel affects composition changes, and, even more important, influences ingot structure. If the steel is too hot, the ingot takes longer to solidify, and segregation increases. In addition, there will be more gas dissolved in the steel.

Here, we used optical pyrometers for temperature measurement until about ten years ago. While useful for measuring tapping temperatures, they were not accurate enough for routine control of temperature during the refining period. We now use the immersion Rayotube (Fig. 4) for bath temperature control. With a graphite insert on the end for protection, we can use the instrument for consecutive readings in the bath without any unusual labor or maintenance. It is rugged and simple in application, and requires no skilled personnel in its operation. With it we are able to obtain an accurate temperature reading in 5 sec. Because of the simplicity of maintenance and the speed of temperature measurement, our melters can obtain reliable temperature control to within $\pm 20^\circ$ F. from meltdown to tap.

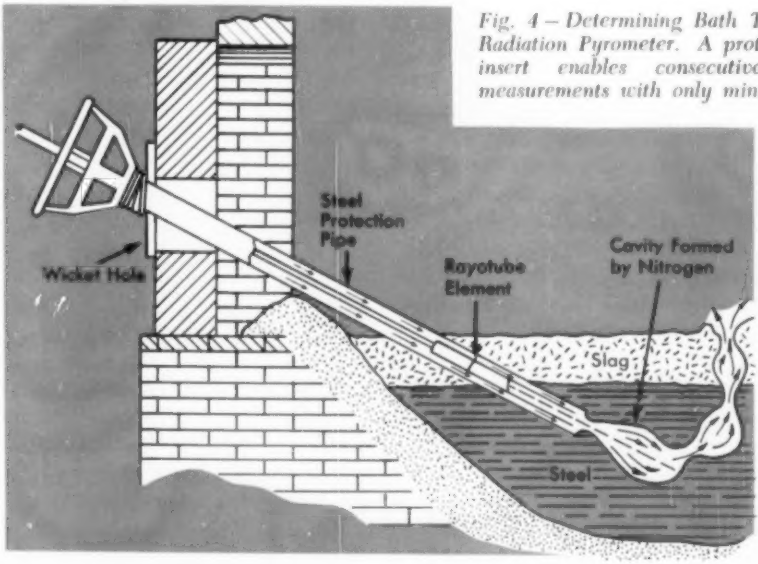


Fig. 4 – Determining Bath Temperature by Radiation Pyrometer. A protective graphite insert enables consecutive temperature measurements with only minor maintenance

Summary

Control of scrap, composition, temperature and freezing in the ingot mold has resulted in major improvements in the consistent behavior of bars and billets. In a critical component made from S.A.E. 6145, which was subjected to hydraulic pressure at its core, only two parts in 90,000 were defective. Before, average rejection rate was about seven parts per 1000.

The sole function of our control system is to eliminate the occasional batches of steel with inferior properties. A more consistent product is possible with off-heats being virtually eliminated. Perfect mechanization cannot yet be promised but the new quality control system does bring it a step nearer.

Edge-Welding Small Containers

*By D. W. GROBECKER**

Gas-tight seals can be readily made in small containers to protect pressure-sensitive or temperature-sensitive electrical and electronic assemblies. Tungsten arc, protected by argon gas, makes edge welds between walls and bases in simple semi-automatic devices. (Kld, Tl)

MANY ELECTRICAL and mechanical components must be in hermetically sealed containers to assure optimum performance. In such closures, organic adhesives must be avoided because these always volatilize to a certain extent, and the resulting condensate may interfere with the proper functioning of the unit.

The fluxes used in soldering and brazing are often detrimental because of condensation or corrosive action. Although normally requiring lower temperature than welding, the base metals must be sufficiently heated to assure wetting by the filler. This, combined with the time required for proper wetting, means that the total heat put into the closure is rather high and the temperature within the container may therefore get so high as to interfere with adjustment, calibration or functioning of the devices. Furthermore, because soldering and brazing result in surface joints, it is difficult to make hermetic closures consistently. Minor contamination of the surfaces can give a lot of trouble. Either inadequate fluxing or excessive flux residues can prevent adequate flow of the liquefied solder.

The alternative is edge-welding of lids to container bodies. The text below describes briefly our investigations to find out:

1. Whether containers could be hermetically closed without objectionable solid, volatile, or corrosive residues.

2. Whether welds could be made and still hold temperatures in the container low enough to avoid damaging heat-sensitive parts.

3. Whether automatic fixtures could minimize human error and assure repetitive operations.

Only welds in which the protruding edges were fused without added filler metal were investigated. Welds were made by the tungsten-inert-gas (TIG) process to avoid necessity for flux. Fixtures for welding torches and containers were devised to balance power input, welding speed, arc length and external cooling.

Since steep temperature gradients can be obtained in this manner, a fused joint requires a low total heat input. Temperatures within most of the component are therefore kept at a low level. With properly designed joints of edges in sheet, 0.030 in. or less, temperatures higher than 400° F. can be restricted to a region less than half an inch from the fused edge without using special heat sinks. Temperatures within the containers increase with the thickness of the exposed edge, the welding amperage, the arc length, the melting temperature, or the thermal conductivity of the material. On the other hand, temperatures are decreased with the distance to the critical elements, the welding speed, the mass of the components, or the effectiveness of the heat sink. The small container shown in Fig. 1 (a 1.2-in. round-cornered square box, 1.5 in. high) could be edge-welded within 0.060 in. of a silver-soldered locating pin without disturbing the mechanical characteristics or tightness of the joint. The containers could be handled during or immediately after the welding with the naked hand. Fixtures were easily adapted to external cooling devices. Special cooling techniques were generally unnecessary, since the fixtures themselves served adequately as heat extractors.

Sometimes these edge joints may be undesirable under dynamic loading. If a thin edge must be exposed, the root of each joint is sharp, and locates a potential stress-raiser. When the materials form brittle welds or if the container is severely deformed, cracks can easily occur at the center of the bead. The container illustrated in Fig. 2 has a heavy threaded top, not only to act as a heat sink, but also to prevent cracks in the edge weld primarily from wall deflection during

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proof testing or variations in external pressure during its service. Such limitations of edge welds under internal pressure, acceleration loading, or vibration should be recognized.

Provisions must be made for proper venting during final closure to avoid expulsion of weld metal by escaping gases. The vent tube, shown at the top of Fig. 2, can be used to purge the container with inert gas and also for leak testing the finished weld, whereupon it can be closed by cold weld crimping, soldering, or (if mass and volume considerations allow) by TIG welding.

Close tolerances at mating edges promote reliable closure with minimum heat input. Gaps 0.020 in. across have been closed by raising the amperage or by slowing the welding speed so as to fuse more deeply into the parent metal. However, this raises the temperature of the work and of the contents (as well as enlarges the weld bead locally). Whether the increased costs of close tolerances are justified must be determined by the difficulties in hand working (rather than repetitive machine welding) or the consequences of highter temperatures within the container.

Oxide films, such as temper colors on steel components, form inside and outside the containers adjacent to the welded region. They can

Fig. 1 – Sectioned View of Small, Gas-Tight Container for an Electrical Relay. Type 302 stainless steel (1.2 in. square). Flanged top edge was welded to flat top in a simple fixture (Fig. 3)

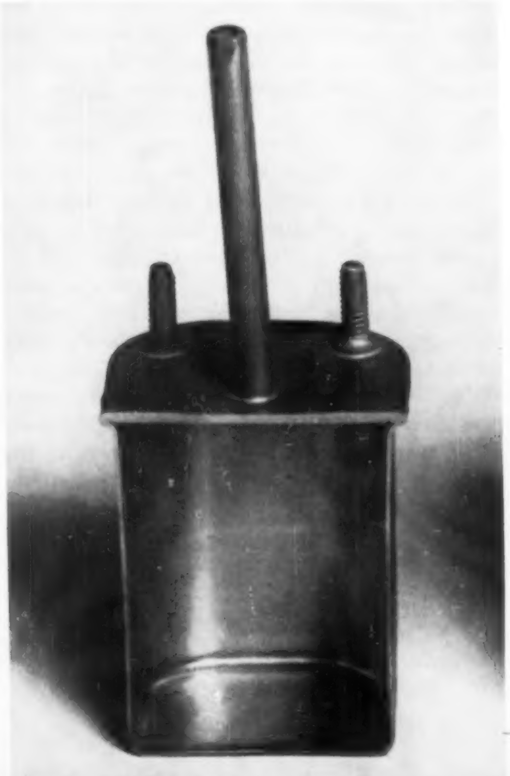


Fig. 2 – Magnified Cross Section Through a 1-In. Container Made of Mild Steel. Threaded cover minimizes mechanical stresses on the weld at top edge

be minimized on the inside by filling the container with an inert gas. It is considered unnecessary to eliminate these oxides completely, because they adhere closely. Outside, of course, they can be sand-blasted if that is considered necessary.

Procedures

Airtight closures have been made successfully in components fabricated from thin sheet of Types 302, 304 and 321 stainless steel, mild steel and aluminum alloys. Attempts to weld joints of mild steel and Kovar to stainless steel have succeeded; difficulty was expected due to the differences in melting points, but these appear to be avoided by the steep thermal gradiants in TIG welding of thin edges. We can assume that satisfactory edge-welded closures can be made in all metals and combinations normally considered weldable.

The mating edges should be cleaned; this can be done easily with emery cloth or a file. For aluminum, alternating current should be used with superimposed high frequency. Containers of mild steel and stainless steel were welded with direct current at straight polarity. Imposed high frequency to initiate direct-current arcs at low amperages appeared advantageous, but would be necessary only for especially thin walls requiring amperages so low as to be normally unstable (that is, less than 7 amp.). For welding amperages between 7 and 12, a high amperage surge (15 to 20 amp.) to initiate the arc was desirable.

Small tungsten electrodes (0.04 or 0.06 in. diameter) were used; 2% thoriated electrodes gave somewhat longer life than pure tungsten. A small ceramic gas cup and a pencil-type torch were satisfactory. Argon gas through the torch at 5 to 10 cu.ft. per hr. prevented oxidation and gave smooth welds without additional flux.

Rigid fixtures assured proper alignment of components beneath the torch. Components as large as a 4-in. cube needed a clamping fixture

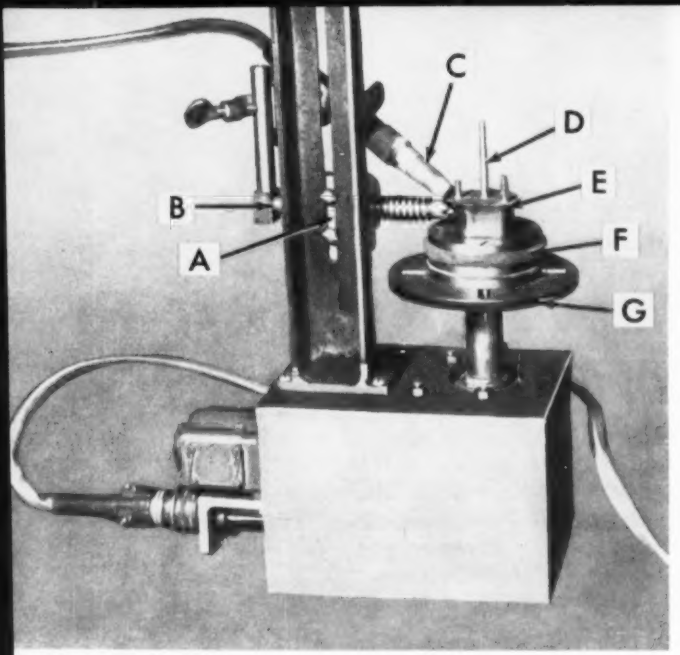


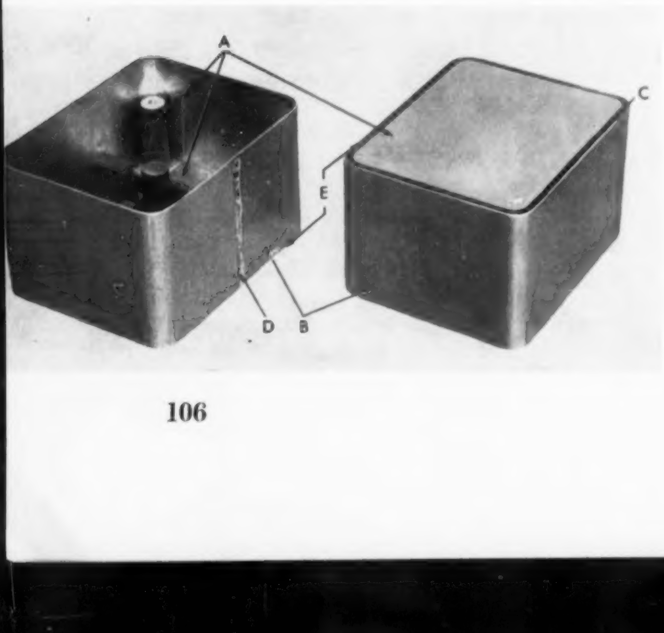
Fig. 3 – A Relay Container Is Shown in Welding Position. The follower bearing block is at A; the can follower and torch positioner at B; and the TIG welding torch at C; D is the relay vent tube. The edge to be welded is at E; the alternating rubber-steel ring mechanism for clamping is at F; and the rotary table is at G

to minimize the effects of differential thermal expansion. However, all fixtures were of simple design and inexpensive ($5 to $150).

In some of our tests, closure was not complete on the first pass because of poor edge contact or a misaligned fixture, but a gas-tight joint could generally be obtained by fusing the faulty section a second time.

Visual inspection seemed to be as accurate as leak testing with the helium mass spectrometer. Containers that appeared visually sound invariably showed leak rates lower than detectable with equipment sensitive to 5×10^{-17} cc. per sec.

Fig. 4 – A Retouched Photograph of a Simulated Power Converter (Upside Down at Right). The heavy base casting of 356-T 51 aluminum (A) serves as a heat sink to protect temperature-sensitive elements during welding and service. The drawn casing (B) is simulated by a butt welded sheet of wrought 6061-T 6 alloy (D). The milled groove (C) in the base exposes an edge for welding to the casing



Representative Jobs

Relay Container – The small container for an electrical relay shown in Fig. 1 was fabricated from a deep drawn Type 302 stainless steel case with a 0.031-in. wall and 0.063-in. cover, which was beveled at a 20° angle to a 0.031-in. edge.

The welding fixture is shown in Fig. 3. The container was centered on the rotary positioner and secured by alternating rings of rubber and steel. A spring-loaded rider B kept the torch up to the edge to be welded. Clearance of 0.030 in. between electrode and edge was considered optimum. A 17-amp. surge initiated the arc, and welding was commenced at 12 amp. with the container motionless. Rotation started when the edge spot liquefied and was accelerated to approximately 1 rpm.

Welding difficulties were aggravated by the generally poor fit between container and cover, and the close proximity of the three locating studs to the fused edge. Misalignment gaps were as great as 0.030 in., and these were hand-filed to 0.010 in. to permit repetitive welding with smooth bead. Leaks did occur in some containers at the silver-brazed locating studs if welding speeds were too slow or if second passes were necessary to fuse misaligned edges. We believe, however, that leaks at the silver-brazed studs could be avoided with proper edge contact and welding speed. A copper-block chill placed over the lid helped to prevent leakers at the brazed studs.

Power Converter – The assembly shown in Fig. 4 is a developmental model of an electric power converter. The final assembly will include temperature-sensitive transistors in addition to other electrical elements. The container is composed of a cast 356-T 6 or 356-T 51 aluminum alloy base and a deep drawn 6061-T 6 or 5052-H 34 cover. (Containers in these models were simulated by a butt welded 0.031-in. sheet of wrought aluminum alloy.) The base of the case was machine-finished to provide a flat surface, and a U groove 0.187 in. deep by 0.125 in. wide was milled around the outer edge to provide a 0.031-in. exposed wall for edge-welding.

Figure 5 shows how a rectangular fixture is

placed around the assembly ⅛ in. below the edge weld, and tight enough to prevent the thin case from expanding away from the thick base during welding.

An alternating current of 60 amp. (with imposed high frequency for stabilization) was used. The torch was held stationary with a gap of 0.030 in. until fusion commenced; movement of the welding head was then gradually accelerated to 14 in. per min. A smooth fairing between initial and terminating beads could be attained by increasing the welding speed just before extinguishing the arc at the overlap. After welding, the thin housing was too hot to handle, but the cast base could be touched with the naked hand within 1 in. of the weld without experiencing any discomfort.

No difficulties were encountered in obtaining hermetic welds after differential expansion was counteracted. However, a number of the assemblies leaked through porosity in the cast base. The high-strength aluminum alloys are believed to be particularly susceptible to bead cracking because of their inherent low ductility when welded. When they are used, it is recommended that frequent proof testing ascertain that crack-free joints are consistently made. Preferably edge welds for aluminum components should be mechanically reinforced with rivets, clamps, or other means (such as the threaded subassembly shown in Fig. 2) to alleviate repetitive stresses on the sealing weld.

Temperature-sensitive pressure switch housing of mild steel is shown cross-sectioned in Fig. 2. This component was edge-welded with an axially positioned inert-gas torch attached to the Heath Ultragraph. The component was fixtured as shown at H in Fig. 5. About 7 cu.ft. per hr. of argon and approximately 50 amp. d-c. straight polarity with imposed high frequency were used. A welding speed of zero (start) to approximately 15 in. per min. (completion) was found to be satisfactory.

Sound leakproof welds were secured on each of five components made in this test series, although one weld was rather rough because of poor power control. The cylindrical configuration and close tolerance fit (± 0.003 in.) made this weld easy.

Conclusions

1. Hermetically sealed containers can be adequately closed by TIG welding with automatic fixtures. Welding is preferable to soldering and brazing from the standpoints of temperature control, minimum residues, and reliability. The objectionably volatile organic compounds associated with adhesives and fluxes are not needed in TIG welding.

2. Required heat sinks and fixtures are generally inexpensive; the average cost for items welded in this program was $50. However, production fixtures would doubtless be more complex to provide repetitive alignment and rapid setup.

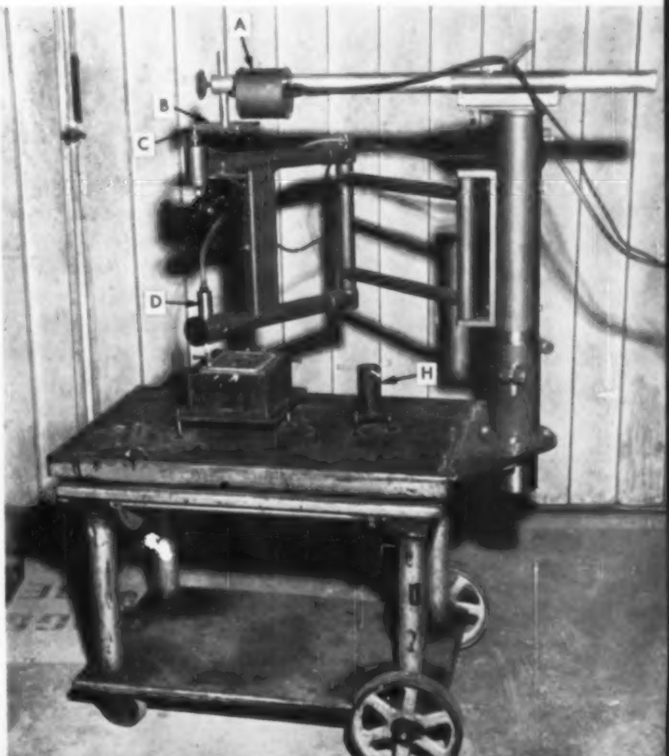
3. Edge fits which consistently meet close tolerances (0.010 in. gap) are required to obtain reliable welds without developing excessive temperatures within the container.

4. Welded edge joints should be used primarily for making airtight closures which will not be subjected to severe mechanical loading. As with spot welds, such a joint provides a natural stress-raiser.

5. Because the process is largely automatic, little skill is required of the operator, particularly after correct machine settings and welding speeds have been determined.

6. If the vessel is not completely closed in the first welding pass, defects can be detected visually. After cooling and mechanical cleaning, faulty sections may be fused a second time.

Fig. 5 – A Heath Ultragraph Cutting Machine Adapted for TIG Welding of a Power Converter. The rotary follower is at A; the templet at B and follower at C. Welding torch and adapter is at D. (The fixture for a temperature-sensitive pressure switch is shown at H)



Light Metallurgy

Preposition Using by Metallurgists

By BRUCE A. ROGERS

BESIDES turning life into a push-button operation, scientists and technologists are changing the English language. As an illustration, they are now converting a floating, badly waterlogged participle into a universal preposition! This change may not be approved at first but its great advantages must ultimately lead to its acceptance. The writer wishes to be the first to recommend dictionary status for this new preposition.

The manner in which one universal preposition may replace an entire group of prepositions is illustrated in this paragraph. Two very simple illustrations are:

1. The mouse was caught using a trap.
2. The mouse was caught using a cat.

In the first sentence, the new preposition "using" replaces "in"; in the second it replaces "by". The advantage of substituting the one word is even more evident in the following sentences noted in my recent readings of technical publications:

3. The densities of the two metals were determined using annealed specimens. (on)
4. . . . although as Sully points out, special treatment must be given to chromium analyzed using Adcock's method in order . . . (by)
5. All bend test samples were cut to approximately 0.4 in. long by 0.2 in. wide using a water-cooled, abrasive, cut-off wheel. (with)
6. The specimen was irradiated with copper radiation using a 0.005-in. (0.1-cm.) nickel filter. (through)

In these six examples, only the five prepositions "in", "on", "by", "with", and "through" have been replaced by "using" but why could not this substitution be extended to *all* prepositions?

One might imagine that each of the other seven parts of speech can be replaced by one – or at least by only a few words.

To be conservative, suppose that it be assumed that the total number of words is reduced to only 20% of the number now in use. The possibilities are staggering. Newspapers and journals could be cut to one fifth of their present size with a corresponding saving of paper plus a marked reduction in the postal deficit and fewer flat postmen's feet. Scientific publications and company reports could be read in one-fifth the time now required. One might even suppose, at first thought, the Government Printing Office could operate on a fifth of its present budget. However, a little reflection brings the realization that such a result would not follow. In order to stabilize the output of words, the Government would increase the number of Federal employees by a factor of five, and thus place an additional burden on the downtrodden taxpayer.

Maybe we should back away from this glamorous proposition and find a sentence to end this essay using.

Heat Program Timer Improves Resistance Welds

*By BURTON B. STUART**

Resistance welding calls for precision control of time and magnitude of current. A unit known as a "heat program timer" causes the secondary welding current to increase gradually so that the joint interface is effectively conditioned before peak current is reached. (W29c, K3, 1-52)

A FEW YEARS AGO, manufacturers of subminiature electron tubes were asked to meet "impossible" standards of reliability in tubes for missile control systems. Welding tiny precision assemblies posed a problem, because no welding equipment existed that would turn out precision welds of consistently high quality.

New Heat Control – Welding engineers from the Raytheon Mfg. Co. developed electronic circuitry for a new kind of automatic precision heat control called a "heat program timer" and built a welding system around this electronic "brain".

In conventional a-c. resistance welding, the high current densities suddenly impressed across relatively high-resistance interfaces cause such high local heat concentrations that portions of the existing barrier film melt. As a consequence, the film shatters and weld particles are splashed over the surface of the material. On the other hand, Raytheon's heat program timer develops a gradual increase in secondary welding current and the electrode-to-work interface is properly conditioned before welding current peak is reached.

A gradual increase in welding current is also used to weld highly conductive metals having too low a resistance at room temperature to produce the necessary heat. After the weld has been made, the current is decreased gradually and serves to anneal the weld in those instances where embrittlement would otherwise occur.

Timing Effect – The heat program timer, when combined with the rest of the equipment (a Thyratron contactor unit and a welding transformer) forms a welding power supply capable of supplying welding current which varies according to a pre-established program throughout three successive time intervals: first, the conditioning period, or "up slope time"; second, the welding period, or "weld time"; and third, the annealing period, or "down slope time".

The magnitude of the welding current throughout each of these intervals is controlled independently. For example, during the up slope time, which is adjustable to last from two to ten cycles of the power line frequency, the welding current increases linearly from an initial, or low heat value, to a final or weld heat value.

During the weld-time period, which is also independently adjustable from two to ten cycles, the welding current remains steady at the weld heat value. During the down slope time, also adjustable from two to ten cycles, the welding current decreases linearly to the low heat value again, then terminates.

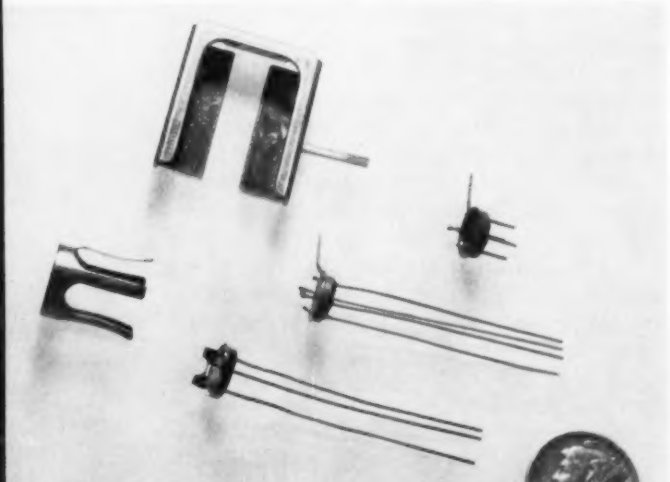
All three time intervals, as well as the weld heat and low heat values, are adjustable by means of control knobs on the front panel of the timer. A simple diagram on the panel indicates clearly the portion of the welding cycle controlled by each knob.

*Raytheon Mfg. Co., Waltham, Mass.

Fig. 1 — Pint-Sized Spot Welding Machine in Action. Transformer, heat program timer and Thyratron contactor are shown, left to right, in the background

Overcomes Foreign Matter — The Raytheon heat program timer varies the weld heat in a pre-established sequence during the welding cycle to produce successful welds — previously considered impractical or impossible — between oxidized, greasy, or otherwise coated metal surfaces in applications involving small metal parts. Most applications involve joining metallic parts for electronic units. Here, the heat program timer's value is especially evident, since it overcomes the effect of foreign matter by properly conditioning the electrode-to-work interface before welding current magnitudes are reached. For example, in welding copper and Kovar parts to thoriated-tungsten filaments, or carbonized plate elements to nickel-iron structural elements, it is especially helpful.

Fig. 2 — Parts Welded With the Aid of the Heat Program Timer Include a Fountain Pen Clutch (Lower Left), Sewing Machine Accessory Bracket (Upper Left), and Several Transistor Bases (Right)



Welding Copper — Spot welding of copper to copper is difficult because of the relatively low resistance of the metal at ordinary temperatures. In the past, welds of this nature have been made either by inserting a higher resistance metal between the two pieces to be welded, or by the use of highly resistive electrode alloys. In both instances, the heat produced within the resistive material is utilized to raise the temperature, and hence the resistivity, of the copper. The first method is expensive and time-consuming; the second is ineffective since it usually produces a brittle, deformed joint.

Using the preheat feature of the heat program timer, the normal resistivity of copper, which is some 2.5 microhms per cm. at 400° K., can be raised to 8 microhms per cm. at 1200° K., making sound welds possible. Similarly, many other low-resistance metals can be welded successfully. The postheat feature of the heat program timer can also be used to reduce or eliminate embrittlement and reduce thermal shock.

Other Applications — The heat program timer is successfully used to join tiny palladium contacts to stainless steel. In the manufacture of crystal diodes and transistors, the timer is used to make pinch-off welds on stainless steel, mild steel, or gold-plated nickel-silver tubing. Also, excellent welds are obtained in joining gold-plated copper "butterfly" elements to Kovar leads. In electronic components manufacture, the timer has simplified and improved the welding of tinned copper wire to nickel-iron cups.

With the aid of this unit, practical, uniform, reliable welds can be made on oxidized or oily surfaces, which are highly conducting, or become embrittled when conventionally welded.

Where Do We Stand in Ceramic Coatings?

*By N. I. CANNISTRARO**

Fig. 1 – Fire Chamber Fabricated for Residential Furnace Is Sprayed With Ceramic Coating to Give Longer Life

While major uses today are in aircraft, rockets and satellites, ceramic coatings are ready for many applications on industrial and consumer products. They add heat and corrosion resistant qualities to low alloys, often permitting them to outperform more expensive, uncoated higher alloys. Special coatings protect against shock, abrasion and fatigue. (L27; SGA-h)

CERAMIC COATINGS may be thought of as varieties of porcelain enamel which are devised to meet specific operating conditions. However, recent requirements for refractoriness have led to the development of compositions which are not glassy in the sense of true porcelain enamels. Present-day coatings can withstand about 3000° F. for short periods and improvements are constantly raising this limit. By fusing special ceramic coatings with advanced metal alloys, scientists have hopes of making new materials which will withstand temperatures up to 5000° F.

Mechanical Properties of Coatings

Specific formulas have been developed which will withstand severe mechanical and thermal shocks. When properly applied, coatings do not require special handling. While a sharp blow may fracture the coating at the impact point, a thin protective film will remain. Such spots will heal during high-temperature operation to protect the basis metal. In bending or flexing, coatings will withstand deflection somewhat beyond the elastic limit of the metal. Shock resistance is most affected by the amount of inert material in the coating's composition. Usually the more inert material which is used, the less the impact resistance; but in a few cases both impact and thermal shock resistance are improved. A prime criterion for excellence of ceramic coatings under thermal shock from mechanical strain is a thin coating. The majority are 0.001 to 0.002 in. thick, and some are under 0.0001 in. in thickness.

Abrasion Resistance – Coatings have values of 5 to 7 on Moh's scale of mineral hardness,

*Vice-President, Bettinger Corp., Waltham, Mass.

Fig. 2 – Inner Liners for J-47 Engine, Formerly Made of Inconel, Are Now Fabricated of Stainless Steel and the Parts Are Ceramic Coated

which means that they are considerably harder than brass, aluminum, copper and many forms of steel. Abrasion resistance can be raised by additions to the coating. Some ceramic coatings have the hardness of topaz.

An example of the good abrasion resistance of ceramic coatings is demonstrated by a normal sheet iron coal chute. It has a service life during the heating season of about six weeks. When ceramic coated, it will last through an entire heating season and is still in such good condition that it is possible to blast off the coating and recoat it.

Fatigue Resistance – Fatigue tests of coated and uncoated samples on a standard Krouse machine at 1700° F. give an average life of more than 1,000,000 cycles for coated samples. Under the same conditions, uncoated samples failed after 160,000 cycles. Similar results were obtained at room temperature.

Ceramic coatings increase lap weld endurance life. The average fatigue life experienced in laboratory tests on lap weld samples is:

Uncoated	686,000 cycles
Uncoated, heat treated 10 min. at 1750° F.	304,000
Ceramic coated	6,000,000

Ceramic coatings act as fluxing agents and permit arc and gas welding of coated parts. When the weldment is made properly, the coating remains intact almost to the edge of the weld area. On alloys with 20% or more nickel, generally, the coating should be removed prior to welding.

Corrosion and Oxidation Resistance

Coatings are available which have a wide range of acid resistance properties. They are being used in applications involving mild organic acids, photography solutions and food processing. For more severe conditions (such as flue pipes, industrial fans, oil refinery equipment, chemical pipe lines and valves, tanks and burner equipment), a class of coatings with a higher degree of acid resistance has been developed. Many of these special ceramics will resist 10% boiling sulphuric acid.

For more severe conditions, which often involve acids at elevated temperatures and pressures, chemical wear coatings are used. They will resist practically any acid with the exception of hydrofluoric.

Acid resistant formulations stand up in molten aluminum and zinc. Chlorine fluxing tubes made of uncoated black iron showed an average life of 30 min. in molten aluminum. When ceramic coated, life of the tube was increased to 96 hr. Thermocouple tubes, similarly coated, give 400 hr. of service in molten aluminum.

One unique use is in coating metal gaskets, jigs and fixtures for use in lead and zinc melting pots. The coating is unaffected by the molten metal, but more important, the metal will not

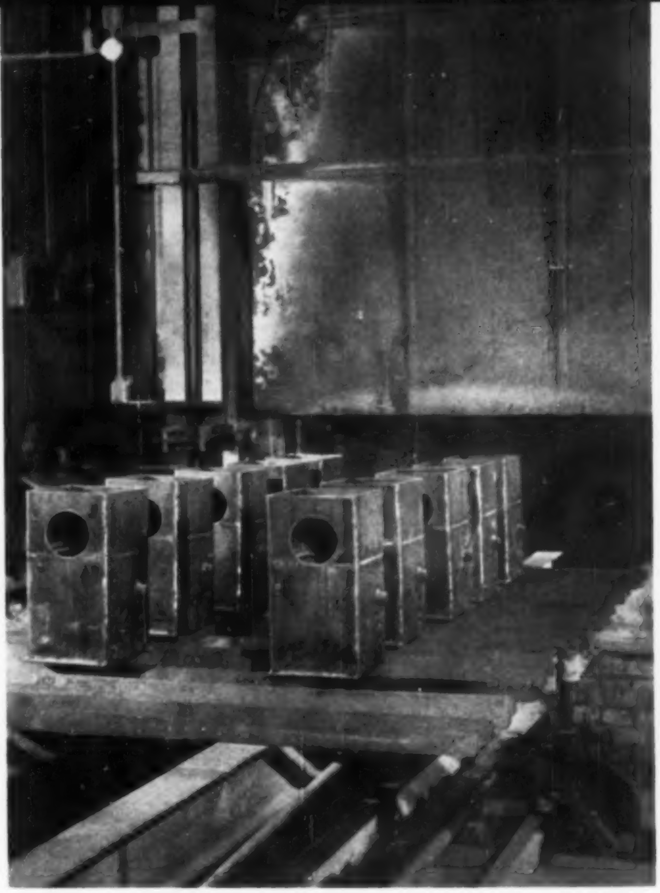


Fig. 3 – Combustion Chambers for Use in Industrial Furnaces Go Into Annealing Furnace Prior to Having a Ceramic Coating Applied

stick to the coating, even when solidified. Some success has been had in coating brazing jigs to keep parts from sticking to them.

Ceramic coatings provide continuous protection against oxidation at 1700° F. and resist oxidation for moderate periods at 2150° F. Coatings for service at high temperatures can be applied on all stainless steels which contain 5% chromium or more and on superalloys such as Inconel, Hastelloy C, N-155, L-605 and the Nimonics. A Type 321 stainless combustion chamber with a ceramic coating (A-418) will give 300% longer life on a turbojet engine than one made of uncoated Inconel and, of course, the stainless is considerably cheaper than the Inconel. If necessary, parts can be machined after coating. Properly selected cutting tools shoulder against the coated metal in a manner to permit clean cuts without serious chipping.

Ceramic coatings developed for antigall applications at elevated temperatures have shown ten times the life of hard chromium plate in contact with Type 310 stainless. Tests were made under wear conditions of 3 psi. and 1 ft. per sec. travel at 460° F. Tests at 1700° F. also show that these coatings will withstand thousands of hours of gall-free service.

Ceramic coatings are playing an important part in development of the turbojet, turboprop, ram-jet and the rocket. Typical uses are on the combustion chamber, inlet guide vane, turbine blade, tail cone and afterburner.

Satellite Coating

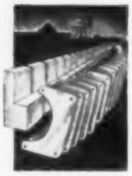
A ceramic coating plays an important role in the orbital flight of the Army's "Explorer". Leading surfaces of the satellite package are partially covered with an aluminum oxide coating. This coating helps in controlling temperature of the instrumentation inside the satellite. It was sprayed on in strips along the outside of the instrument vehicle in the nose cone to the fourth-stage rocket motor section.

When it is on the dark side of earth, the satellite radiates heat to the coolness of empty space. When on the sun side of earth, it absorbs heat at a terrific rate. This temperature differential is close to 800° F. – from about 150° below zero on the cold side to some 600° F. on the hot side. Since the satellite circles earth once every 118 min., these fluctuations in temperature occur every hour, giving rise to severe thermal stresses.

The forward shell of the satellite is 25% covered by eight equally spaced strips of aluminum oxide, each ¼ in. wide. It is this stripping which keeps the temperature range inside the satellite at 50 to 86° F. and protects the sensitive instruments and electronic equipment.

Nonmilitary Uses

A number of commercial applications are moving into the ceramic coating picture. The coatings available (Bettinger uses 20 on a production-line basis in some 400 specific applications) can be grouped into three basic types – those for (*a*) low-carbon or low-alloy steels, (*b*) Types 300 to 400 series stainless, and (*c*) premium high-temperature alloys. Coatings for electronic uses and for resistance to corrosive liquids at high temperatures (*Cont. on p.* 189)



Short Runs

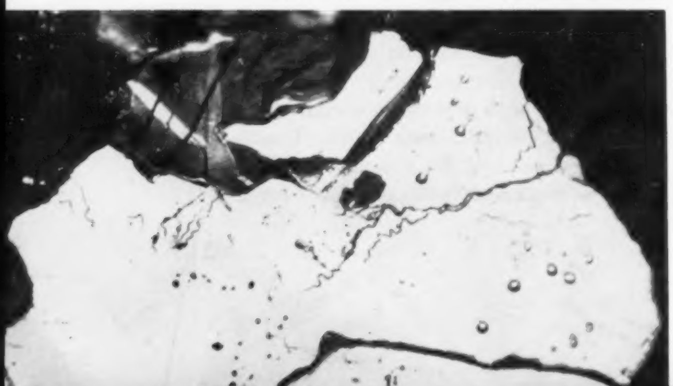
A Magnetic Specimen Mount for Fractography

*By D. B. BALLARD and J. A. BENNETT**

Fig. 1 — Magnetic Specimen Mounted on the Stage of a Metallographic Microscope

Fig. 2 — Detail of Magnets Showing Teflon Disks on Which the Inner Magnet Slides. Disk carrying the specimen is adjustable

Fig. 3 — A Fractograph Made With the Aid of a Magnetic Mount. Twinning is present on a facet of the fracture surface of a high-purity zinc fatigue specimen. 400 ×



Zapffe and Clogg introduced the term fractography to describe the micrographic study of cleavage facets on fracture surfaces and pointed out some of the possible uses of the technique in metallurgy. One of the factors that has limited its application is the difficulty of aligning the desired facet perpendicular to the optic axis of the microscope, particularly when the fracture surface is rough. A magnetic specimen mount developed in the mechanical metallurgy section of National Bureau of Standards gives an inexpensive means of accomplishing orientation with sufficient precision for many uses.

The complete mount consists of a transparent hemisphere with a wide supporting flange, a permanent horseshoe magnet on which the specimen is mounted, and a control magnet. As shown in Fig. 1, the specimen magnet is held on the inside of the hemisphere by the outer control magnet. Thus the specimen can be oriented in any desired relation to the stage of the instrument on which the hemisphere is mounted, or can be rotated about the axis of the magnets.

The hemisphere used on the pilot model of this mount was obtained by cutting in two a plastic toy. Figure 2 shows the magnets in more detail. The specimen is fastened to the disk on the specimen magnet with an adhesive such as beeswax, and the position of the disk relative to the magnet can be adjusted so that the surface to be examined is at the center of the hemisphere when the mount is assembled. The surface of the specimen magnet is ground to approximately the same radius as the inside surface of the hemisphere, while the outer control magnet has a concave surface of about the same radius. In order to eliminate jerkiness in the motion of the inner magnet, three Teflon disks were cemented to the specimen magnet and the inner surface of the hemisphere was coated with a soap film.

*Metallurgists, National Bureau of Standards, Washington, D.C.

The force between the magnets can be adjusted by changing the thickness of the disks.

In the first figure the mount is shown in place on an inverted-type metallographic microscope where it has been used for examination of the facets of fracture surfaces in metals, such as that shown in Fig. 3. This area provided a good example of the utility of the instrument, as the surfaces of the twins and the small facets at the top were not exactly parallel to that of the main facet. Consequently it was possible to obtain a contrast between any two desired planes by moving the specimen on the mount so that one of them gave a bright reflection.

The mount can be used with upright microscopes for the examination of opaque specimens, such as minerals, and with modification can be adapted for transparent specimens. It might also be useful for orienting specimens in other instruments such as X-ray diffractometers. By inscribing reference lines on the hemisphere and fiducial marks on the outer magnet, it is possible to determine the orientation of the specimen relative to the flange of the hemisphere.

Quenching Titanium Under Inert Atmosphere

*By E. C. BUCKINGHAM**

In an endothermic furnace atmosphere, oxygen and nitrogen contaminate titanium, caussing brittleness. There is no convenient mechanical way to remove this surface contamination – sand-blasting and light machining are both unsatisfactory. The original manufacturer avoids contamination by vacuum melting, but the vacuum process is not ordinarily available to the production heat treater. But by eliminating these two bad actors, oxygen and nitrogen, the heat treater can reap the full advantage of the high strength-to-weight ratio offered by titanium and its alloys.

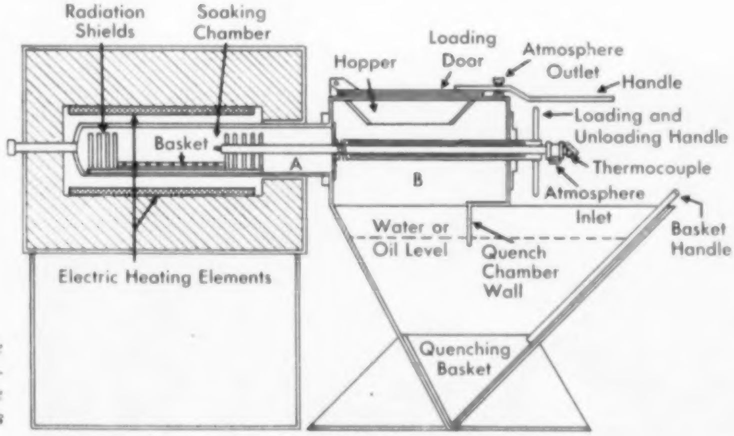
This has been done in the new quenching furnace (see drawing below) installed at Metallurgical Consultants, Inc., Maywood, Calif.

Unique Design – This furnace controls the atmosphere not only during the heating cycle, but also throughout the loading and quenching cycles. The following sequence of operation illustrates the pertinent design features.

Titanium parts, weighing up to 40 lb., are fed into a hopper in the top of the quench chamber (B). The parts then drop into a metal basket mounted on the end of a loading arm. The quench chamber (B) and the soaking chamber (A) are purged by approximately five volumetric changes using helium or argon as the inert gas. During this purging, which takes approximately 5 min., the parts are protected from undesirable preheating by radiation shields mounted on each end of the basket. To insure uniform heating, electric elements have been placed over the entire inner surface of the cylindrical heating chamber.

The basket is advanced by sliding the loading arm into the soaking chamber. The chamber is then sealed. During the heating cycle, the inert gas is introduced into the soaking chamber through the hollow loading arm. It passes over the work, then flows through a connecting line

*Field Metallurgist, Pacific Scientific Co., Los Angeles.



Section View of the Furnace and Quenching Unit. Inert atmosphere exists in both the quench and soaking chambers

(not shown) into the quench chamber and exhausts by bubbling under the quench chamber wall that extends into the quench medium.

This much of the heat treating cycle could be performed by a conventional inert atmosphere furnace. However, since a poor quenching technique can materially offset the physical results, the specific advantages of this operation appear during the quenching action.

Quench temperatures are determined by the beta transformation temperature of the particular alloy being quenched. With the parts soaked at 1625 to 1725° F., the basket is withdrawn from the furnace and the arm, with the basket attached, is rotated to allow the parts to spill into the quenching liquid. They are thoroughly quenched in 2 to 3 sec. and each part is quenched individually.

Because the quench chamber also contains an inert atmosphere, these finished titanium parts have a clean, bright to light peacock-blue color. In a typical operation, titanium bolts are age hardened to Rockwell C-36 to 40. Tensile strength of 4% Al, 4% Mn titanium bolts ranges from 100,000 to 180,000 psi., and those containing 6% Al, 4% V from 180,000 to 190,000 psi.

A refinement of the present production unit involves the use of a vacuum purge to reduce the time required to completely remove the oxygen trapped in the load.

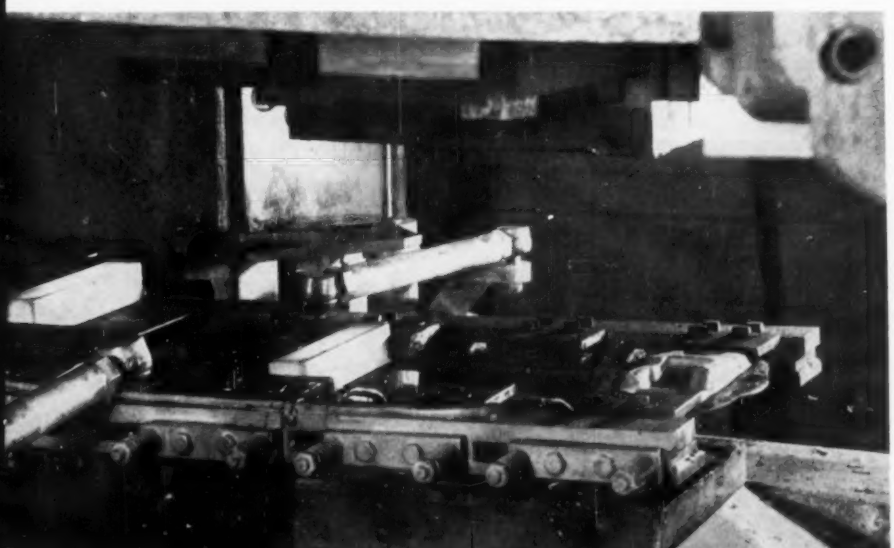
Automatic Press for Small Forgings

A new forging press has been developed by Erie Foundry Co. for high-volume production of parts, such as connecting rods, stem pinions, ring gears, track links, and wheel hubs. Automatic transfer between each forging stage reduces both the number of presses and amount of labor usually required.

The feeding mechanism, illustrated by the photograph, is simple in design and operation. A conveyer delivers the hot bar from the furnace through the left window of the press where it is positioned at the pickup station by a pusher. The feeding mechanism, actuated by cams, operates through linkages to advance the part from one stage to the next. Fingers grasp the hot bar at each end and lift it into position for partial forging. As the fingers move to the side and return to get the next bar, the press comes down to forge the first bar. The press lifts, and the feeder closes to grab the second bar and partial forging. Both are advanced to their next positions. Again, the fingers separate and the press comes down to partially forge the second bar and finish forge the first bar. Feeding and press operations continue as long as material is supplied.

As the 2500-ton press is set up now to forge track links, no trimming operation is included. However, there is room to add an extra trimming die, if needed. Only one man is required to monitor the operation. He stands at the side of the press to observe operations and close it down if troubles develop.

The press runs 40 strokes per min., and can make a finished forging with every stroke. Since die life would be quite short at this high rate, the press, as it now operates, forges a part every two strokes, or 1200 per hr. This high production rate, coupled with the lessened labor requirements, opens the way to new economies in forging of small parts.



Feeding Mechanism for Automatic Forging Press. Bar at left is ready to be picked up, bar in center is ready for semifinishing die, and finished forging at right is about to drop into tote box

Is heat treating costing you more than it should?

A FRANK APPRAISAL OF YOUR METHODS MAY WELL BE IN ORDER!

Every so often, it pays to re-evaluate every production phase in the light of new developments. This is especially true of heat treating. A method change here or a piece of more modern equipment there can spell vitally important cost savings . . . a fact that Ajax has proved in hundreds of cases.

The outstanding basic advantages of salt bath heat treating for most applications are now, of course, well known. These include: faster, more uniform heating by conduction; elimination of atmosphere problems; negligible distortion; ease of selective heating; faster production in less space with unskilled labor; and various others.

Not so well known, however, are important recent developments in salt bath furnace types. The new Ajax design in which a pair of submerged electrodes can be changed in a short time without tearing down the pot is an example. Ajax Cataract Quench Furnaces which give molten salt quenching power equal to that of oil are another. Ajax gas-fired salt baths are still another.

Equally important, there have been 10 league strides in applying salt bath processing to still better advantage and in mechanizing it for substantial labor cost reductions.

As salt bath pioneers and with connections in many parts of the world, it is only natural that Ajax should have led in most of these while being thoroughly familiar with all.

The chief product of Ajax is heat treating "know how" . . . not merely the largest assortment of salt bath furnace types on the market.

Thus Ajax heat treating specialists welcome the opportunity to make recommendations from the background of their unsurpassed experience. While freely admitting that salt baths do not answer every need, they work on the demonstrable knowledge that Ajax Salt Bath Furnaces are scoring important cost reductions on an ever-increasing list of applications while materially boosting quality and efficiency on many.

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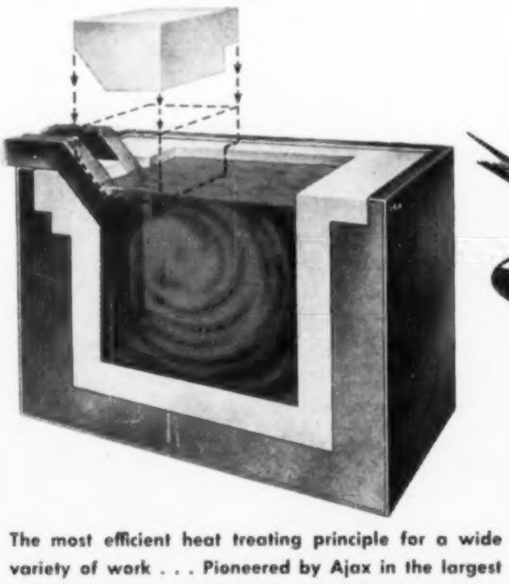

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Internally heated.
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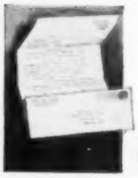


Correspondence

Fatigue Failures in Hydraulic Tubing

Sierra Madre, Calif.

In the July issue of *Metal Progress*, C. S. Yen and J. L. Waisman describe failures in tubing that had been subjected to internal fluctuating pressure ("How to Make Hydraulic Tubing Last Longer", p. 88). The failures are identified as fatigue cracks occurring in the flattened sections of tubing bends.

The authors give the three following contributing causes for the fatigue cracks: *(a)* surface roughness, *(b)* "specified tensile strength" of the metal from which the tubes were made, and *(c)* "flattening which occurred at bends when the tubes were formed". They state that "flattening in the formed portion (of the tube) was the principal factor causing failure in the observed locations" but they did not explain why flattening constitutes a serious fatigue hazard.

The dominant cause of failure in these tubes, as in a large percentage of all fatigue failures of machine parts, was residual tensile stress. In these tubes the damaging residual tension was introduced by the flattening of the tubes in the bending operation.

It is well known that local plastic deformation produces residual stress of opposite sign to the applied stress causing the deformation. The metal on the inside surface of the tube wall at the points B and B of the authors' sketch (reproduced herewith) was plastically deformed by compression, while metal on the outer surface of the tube wall at points B and B was plastically deformed by tension.

Upon release of the bending load, elastic recovery of the metal tends to put the tube back into its original cylindrical shape, and as a result the outer surface became residually stressed in compression and the residual stress on the inside of the tube wall at points B and B, where the fatigue cracks originated, was tension.

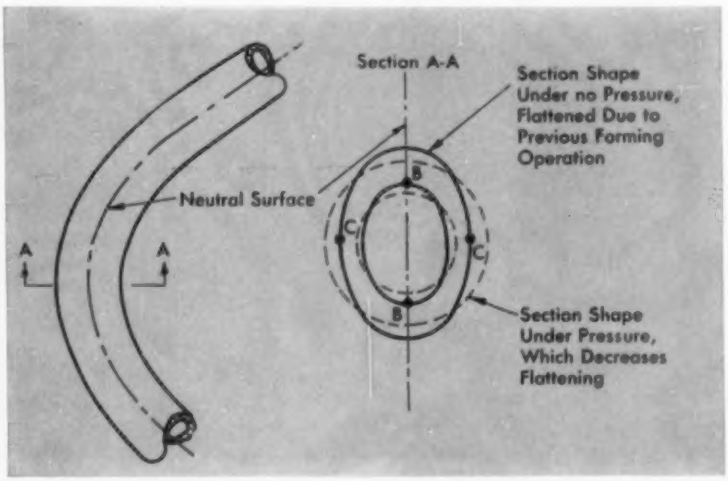
The direction of plastic bending in the tube walls at C and C was opposite to that of B and B; hence the resulting residual stress, after the release of the bending load, was compressive on the inside and tension on the outside. The latter is indicated by the authors as the points of occasional failure C and C.

Note that the fatigue cracks, whether at B or C, originated in the surface that was residually stressed in *tension*. Note also that cracks originated at C in spite of its relative freedom from severe stress-raisers such as the internal imperfections shown by the authors' Fig. 7.

The authors stated that "fatigue life decreased progressively as the amount of flattening increased". This would be expected, because the residual tensile stress at the origin of fracture also increased with increased plastic deformation.

Furthermore, the authors' observation, that "failure locations were at B and C locations, most failures occurring at B, though an occasional one began at the indicated outside location", conforms to the expected relative magnitude of the residual tensile stresses. The residual tensile stress at B and B was greater than at C and C because of the greater plastic deformation of the former due to the greater metal thickness and the greater change in the radii of curvature.

It should also be noted that fluid pressure within the tube increases the tensile stresses at internal points B and B and also at external points C and C because, as is shown in the authors' figure, it decreases flattening. The resulting bending *increases*



High-Tension Locations Due to "Breathing" of Flattened Section. The points marked B on the inside diameter are the points of highest stress

Fatigue Failures . . .

the radius of curvature at B and B but *decreases* the radius of curvature at C and C, thereby stressing the metal in the same sense as the residual stress.

It is not enough that metallurgists, engineers and designers heed the warnings stated in the first paragraph of the Yen and Waisman article. Knowledge of the magnitude and direction of residual stress is often more important than any or all of the above-mentioned warnings.

We must keep in mind three things: First, that fatigue failures are tensile failures and that the effective stress is the sum of the applied stress and the residual stresses; second, that surfaces, whether rough or smooth, are much weaker in fatigue than sound subsurface metal; and finally, that the elastic limit of steel (and probably also of nonferrous metals) is only about two-thirds that which is determined by static measurements.

The fatigue strength of the tubes described in the July article can be increased by reducing the harmful residual tensile stress. This can be accomplished by heating or by applying 5 to 10 cycles of internal pressure which exceed the elastic limit of the tube as measured by permanent reduction of flatness.

In thermal reduction of harmful residual stresses, it must be remembered that the residual stress remaining after annealing will approximate the static elastic limit of the metal at the annealing temperature.

It may be possible to combine these two treatments and thus reduce the residual stress to a desired maximum by annealing at lower temperature as well as by lower internal pressure.

JOHN O. ALMEN

Hazards From Fall-Out*

LEMONT, ILL.

In the very considerable discussion of the dangers of radioactive fall-out, it has often been forgotten that the amount of fall-out which we have experienced up to the present time actually increases the existing human burden of radiation by less than 1%. In my opinion, any conceivable harm which this might do to the lungs, for example, pales into insignificance beside the pandemic of lung cancer due to causes now known to be preventable – not to mention the human and material destruction that would be wrought by another war.

The campaign that has been waged against testing of atomic weapons has been carried out in large part by persons with idealistic motives, and also to some extent on a political basis. Its fundamental

*This statement by the director of the division of biological and medical research at Argonne National Laboratory was written at the request of the Editor-in-Chief of *Metal Progress*. It was written before the recent exploits of our Navy's submarines under the polar ice cap. Its last paragraph, therefore, is especially revealing in the light of the action of the Danish government in excluding its ports to the submarine Skate.

Hazards . . .

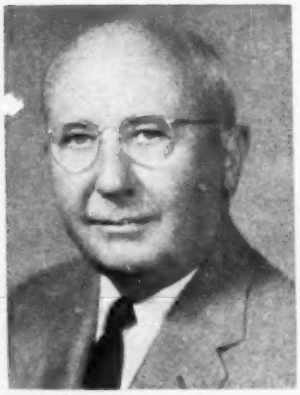
argument is that *any* amount of radiation, no matter how small, produces its proportional share of damage as reflected in leukemia, cancer, or genetic change. As regards leukemia and cancer, the bulk of evidence familiar to those scientists engaged in experimental and clinical cancer research suggests that this is not so. Some recent studies on irradiated mice also bring into question the argument as to genetic changes. The difficulty seems to be that these questions as to the effects of small increments in radiation on a few individuals can never be proven directly, and that to prove them experimentally would require the use of many millions of experimental animals. It is only in the field of theoretical biology that we may expect the final answer, and it is to be hoped that in the meantime we may find preventives or cures of cancer, and ways and means of alleviating genetic damage.

The only way in which questions of weapons tests can be truly resolved is in terms of their possible benefit. Insofar as they are beneficial in terms of providing information as to the best medical defense against them, their value, to any and all nations, obviously outweighs any harm they may do. The better the exchange of information becomes, the larger the ratio of benefit to harm becomes.

A most important matter, which has hardly been mentioned publicly, is the effect of the present hysteria on the future of the peaceful uses of atomic energy. With an expanding world becoming increasingly dependent for its economic survival on atomic energy, we must guard against psychological barriers against it; and they are being created by the increasing fear of radiation. There is no doubt that increasing use of petroleum has brought in its trail an increasing contamination of the atmosphere with chemical compounds known to produce cancer. All of these things must be brought into perspective so that we may get a truly balanced view of the rewards and hazards of human progress.

AUSTIN M. BRUES, M.D.,
Director
Div. of Biological and Medical Research
Argonne National Laboratory

Personal Mention



Edgar H. Dix, Jr.

EDGAR H. DIX, JR., internationally recognized as the dean of aluminum metallurgy, has retired as assistant director of research for Aluminum Co. of America, New Kensington, Pa.

Mr. Dix has been directly or indirectly responsible for the development of the majority of aluminum alloys used today. Among his significant contributions to the light metals during a research career spanning nearly half a century was alclad strong alloy sheet, which played a vital part in World War II and continues to act an important role in the construction of modern aircraft. His recent major interest has been in the development of aluminum and magnesium alloys for industrial applications, such as tank cars and truck bodies.

Receiving his metallurgical education at Cornell University, he joined the Army's Bureau of Aircraft Production in Pittsburgh in 1918, and the following year, as assistant engineer of tests for Aluminum Castings Co. in Cleveland, began research on aluminum alloys. After a short time as chief of the metals branch, material section, of the engineering division of the U.S. Army Air Service, in 1923 he began his career at Alcoa as chief of the metallurgy section of the research laboratories in New Kensington, rising to chief metallurgist in charge of metallurgy sections of the research laboratories both at New Kensington and Cleveland. Since 1942 he had served as assistant director of research.

Mr. Dix's contributions to metallurgy have received wide recognition. He was awarded the Francis J. Clamer Medal by the Franklin Institute for his "meritorous contributions to the development of high strength corrosion resistant aluminum products" in 1947 and received the honored Albert Sauveur Achievement Award of the American Society for Metals in 1956 for his outstanding work in aluminum alloy research. He was further honored this year by the award of an honorary degree as Doctor of Science from Carnegie Institute of Technology.

Paul Gordon has been advanced to the rank of full professor of metallurgical engineering on the faculty of Illinois Institute of Technology, Chicago. Dr. Gordon was in charge of physical metallurgy for the U. S. Atomic Energy Commission at Massachusetts Institute of Technology before coming to Illinois Tech in 1949. In 1951 he joined the faculty of the Institute for the Study of Metals at the University of Chicago, then returned to Illinois Tech as an associate professor three years later.

M. Robert Larson has joined the staff of J. A. Kozma Co., Dearborn, Mich., after more than 15 years' experience in sales and engineering of industrial furnaces.

E. A. March, former assistant works manager at the Crucible Steel Co. of America's Sanderson - Halcomb Works in Syracuse, N. Y., has been appointed division superintendent, technical services, at the company's Midland, Pa., Works. Mr. March, who joined Crucible in 1946, will be responsible for metallurgical standards and procedures, quality and process control and the chemical and inspection departments at Midland.

Walter Lojewski is now vice-president of the recently organized steel treating corporation, Steel Treaters, Inc., in Oriskany, N. Y.

E. M. H. Lips, for many years manager of metallurgical research for Philips' Lamp Factory at Eindhoven, Holland, has resigned to become technical director of Lips N.V. of Drunen, Holland, one of the largest bronze foundries on the continent, specializing in propellers, bearings, strip and rod, and nonferrous alloy ingots. Many Americans have met Dr. Lips during his attendance at both World Metallurgical Congresses, or during his visits to Washington as representative of the Dutch government on technical matters.

Donald G. Hazlett has been promoted to product engineer for Vulcan Mold & Iron Co., operating at both the company's Latrobe, Pa., plant and its Chicago district plant in Lansing, Ill. He joined Vulcan in 1951 after graduation from Pennsylvania State University.

Garnet P. Phillips has been appointed foundry research consultant, manufacturing research, for International Harvester Co., Chicago. Since joining International Harvester in 1935, he has held various supervisory positions. He played a major role in establishing the foundry research laboratory and since 1949 was general supervisor of foundry research. An active ASMer, he served as chairman of the Tri-City Chapter in 1932-33.

John P. Strand has been named division superintendent, titanium, at Crucible Steel Co. of America's Midland, Pa., Works, following the full integration of the company's titanium manufacturing into the plant's operations. He joined Rem-Cru Titanium, Inc., then jointly owned by Crucible and Remington Arms Co., in 1953 and served in various capacities until he was made superintendent of operations earlier this year.

John Chipman, professor of metallurgy at Massachusetts Institue of Technology, has been elected president of the Metallurgical Society of the American Institute of Mining, Metallurgical, and Petroleum Engineers for one year beginning next February. **Carleton C. Long**, director of research, Zinc Smelting Div., St. Joseph Lead Co., Monaca, Pa., was elected vice-president and will succeed Dr. Chipman in 1960.

Personals . . .

Carl S. Walton, formerly chief metallurgist at the Midland, Pa., Works of Crucible Steel Co. of America, has been appointed product metallurgical engineer in the customer technical service section of Crucible's metallurgical division in Pittsburgh.

Stephen F. Madden has been promoted to assistant manager in charge of tool and die steel sales in the steel sales division of Firth Sterling, Inc., Pittsburgh. In addition, he will continue in his present capacity as metallurgical engineer.

A. E. Nehrenberg, formerly research supervisor, has been named section manager, technical development, for Crucible Steel Co. of America, Pittsburgh. Mr. Nehrenberg has been associated with Crucible since 1945 in supervisory posts and special assignment with the company's research activities at Harrison, N. J., and in Pittsburgh.

John S. Rinehart, assistant director of the Smithsonian Astrophysical Observatory and an astronomy research associate at Harvard University, has accepted a position as full professor of mining engineering at the Colorado School of Mines. In addition to teaching courses dealing with chemical and physical make-up of explosives, Dr. Rinehart will also become director of the school's Mining Engineering Research Laboratory.

Howard B. Myers has been named metallurgical sales division manager of Tennessee Products & Chemical Corp., Nashville, Tenn. Mr. Myers recently joined the company after 19 years experience in the metals industry, most recently in a sales capacity with Pickands Mather & Co., Detroit.

Ray P. Dunn has been appointed technical director of the Lindberg Melting Furnace Div., Lindberg Engineering Co., Chicago. Mr. Dunn comes to Lindberg after four years as director of metallurgy for U. S. Reduction Co., East Chicago, Ind.

Stephen Maszy is now lead structures engineer at Chance Vought Aircraft, Inc., Dallas, Tex.

XXIX

This is the twenty-ninth of a series of advertisements dealing with basic facts about alloy steels. Though much of the information is elementary, we believe it will be of interest to many in this field, including men of broad experience who may find it useful to review fundamentals from time to time.

Cold-Finishing of Alloy Steel Bars: Grinding and Polishing

Grinding and polishing of cold-drawn or turned alloy steel bars is the concluding discussion on the subject of cold-finishing. In the processes of turning and polishing, and grinding and polishing (both of which require removal of surface metal), the surface finish of the bars, as well as their dimensional accuracy and alignment, are improved. But the ultimate in quality of bright, smooth surface finish and accuracy is produced by grinding and polishing of either cold-drawn bars or turned bars up to 4-in. diam, inclusive.

GRINDING AND POLISHING

Sizes up to and including 4-in. diam, are generally confined to centerless cylindrical grinders. Larger sizes are ground on centers. A centerless grinder includes a grinding wheel, a regulating wheel for applying pressure against the bar, and a work-rest blade which both supports the bar and guides it between the wheel spacing. Automatic feed of the whole length of the bar is accomplished because the regulating wheel is set at an angle of inclination with respect to the grinding wheel, and thus within this system the bar rotates and feeds during grinding. The bar is then polished to a mirror-like finish by passing through straightening rolls.

Both processes of turning and polishing, and grinding and polishing, are applicable to normalized, annealed, or heat-treated carbon and alloy bars. These operations do not materially affect the mechanical properties. For this reason, the end product can be machined unsymmetrically, with little or no tendency to warp.

Fundamentals Only. In the past four advertisements, we have outlined *basic fundamentals only* on the cold-drawing of alloy bars, the effect of cold-drawing, turning and polishing, and grinding and polishing.

Please keep in mind that Bethlehem metallurgists have given long study to specifications with respect to chemical composition, grain size, hardenability, machinability, and the like, of cold-drawn alloy steel bars. If you would like additional information on cold-drawn products, or alloy steels, our metallurgists will gladly give you all possible help, without cost or obligation.

When you are ready for new supplies of alloy steels, Bethlehem can offer the full range of AISI standard grades, as well as special-analysis steels and all carbon grades.

If you would like reprints of this series of advertisements, please write to us, addressing your request to Publications Department, Bethlehem Steel Company, Bethlehem, Pa. The subjects in the series are now available in a handy 40-page booklet, and we shall be glad to send you a free copy.

BETHLEHEM STEEL COMPANY
BETHLEHEM, PA.

On the Pacific Coast Bethlehem products are sold by Bethlehem Pacific Coast Steel Corporation. *Export Distributor:* Bethlehem Steel Export Corporation

BETHLEHEM STEEL

BETHLEHEM STEEL

Personals . . .

Charles W. Sherman has assumed new duties as technical director of Jones & Laughlin Steel Corp.'s Stainless and Strip Div., Pittsburgh, in charge of the division's research and development activities. Until his new appointment, he was a senior research associate engaged in studies on stainless and alloy steels.

Robert M. Breckenridge has been transferred from sales representative for Selas Corp. of America's St. Louis sales district to sales representative of the Houston, Tex., district. Mr. Breckenridge, who joined Selas in 1947, was assigned to the St. Louis district in 1954.

Roy C. Raymond has been promoted to the position of manufacturing superintendent of the Singer Mfg. Co., Bridgeport (Conn.) Works.

John W. Pridgeon, formerly at Michigan State University, was recently appointed to the staff of the Y-12 Plant at Oak Ridge National Laboratory, Oak Ridge, Tenn.

Edward E. Reynolds has been named chief metallurgist, alloy research and development section, at the Brackenridge, Pa., research center of Allegheny Ludlum Steel Corp. Dr. Reynolds formerly directed the company's high temperature and valve steel research at the Watervliet, N. Y., Works. He has been succeeded in that position by **Richard K. Pitler**, who was formerly supervising metallurgist in valve steel research.

Donald F. Ross has been named Ohio branch manager for Dayton by the Carpenter Steel Co., Reading, Pa. Mr. Ross, who joined Carpenter as a sales representative in 1953, had been assistant branch manager since 1957.

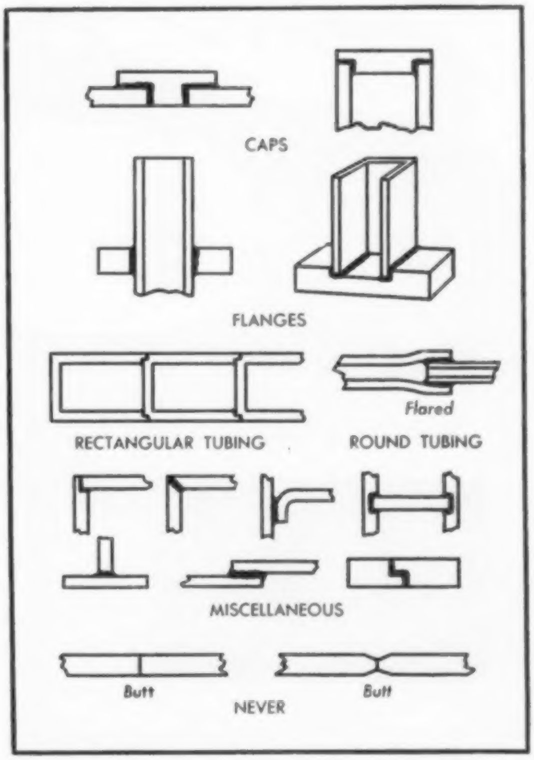
E. T. Walton, former metallurgical engineer, has been named manager, customer technical services, for Crucible Steel Co. of America, Pittsburgh. At the same time, **James A. Kearney**, former group leader in the corporate development section, has been appointed manager, materials and processes. Mr. Walton has been affiliated with Crucible since 1923 while Mr. Kearney joined the company in 1930.

From Park Research Laboratories

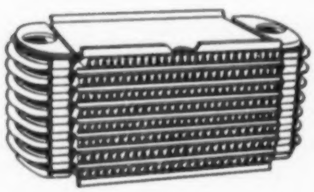
Aluminum Brazing in Salt Baths

Dip brazing of aluminum parts has developed to the point where such operations are on a production basis. Aluminum brazing in salt baths is now widely used in the fabrication of such items as heat exchangers, wave guides, refrigerator evaporators, fuel tanks and aircraft parts.

Dip brazing in molten salt is the most effective, practical and economical method of joining aluminum in many cases. Aluminum of extremely thin gage can be handled without damage from pitting or distortion. Tensions are spread evenly along the joints as opposed to stress points formed by spot welding or riveting. Joints produced by the brazing of aluminum parts are as strong as those produced by any other method. Thousands of inaccessible joints in a single unit can be handled by the dip brazing method. Increased production rates and reduced scrap losses lower unit costs.



THE HEAT EXCHANGER—A GOOD EXAMPLE



The heat exchanger, assembled from alternate corrugated and formed aluminum sheets, is a good example of the type of work handled advantageously by dip brazing. Thousands of lineal feet of perfect joints were made simultaneously in the part shown.

MANY ADVANTAGES OFFERED

Among the many advantages offered by salt brazing of aluminum are:

Minimum distortion because of uniform heating, close temperature control and the buoyancy of the molten brazing salt.

Savings in floor space and equipment since molten salt is 4 to 6 times faster than conventional furnaces and long cooling chambers are eliminated.

Assemblies of various sizes and shapes can be brazed simultaneously.

All joints are brazed at one time although selective brazing is possible.

ESPECIALLY APPLICABLE TO JOINT DESIGN AND FIXTURES

The close tolerances required of aluminum microwave components can be satisfied by dip brazing. Aluminum manufacturers' literature contains designs for self-locating joints and proper clearances. Use of these joint designs eliminates elaborate fixtures and costly assembling. Joint designs suitable for dip brazing aluminum parts are illustrated above.

PARK ALUMINUM BRAZING SALTS OFFER SUPERIOR QUALITIES

Park Aluminum Brazing Salts are superior to other fluxes because of their better fluidity, greater stability, freedom from sludge and ease of cleaning. They act as both flux and heat transfer medium for all dip brazing operations on aluminum alloys. Joints can be made by using wire rings, flat shims or with brazing sheet.

For detailed information on Park Aluminum Brazing Salts and their application, send coupon for technical bulletins. Samples for experimental treatment may be submitted, if desired. Send to PARK CHEMICAL COMPANY, 8074 Military Avenue, Detroit 4, Mich.

PARK CHEMICAL CO.
8074 Military Ave., Detroit 4, Mich.

Please send your technical bulletins on Aluminum Brazing Salts to:

Name__________

Company__________ Position__________

Address__________

City__________ State__________

Personals . . .

J. E. Jacobs was recently appointed assistant vice-president of operations for Bethlehem Steel Co., Bethlehem, Pa. Before receiving his current assignment, he was general manager of Bethlehem's Lackawanna, N. Y., plant.

Thomas L. Case has joined C. I. Hayes, Inc., of Cranston, R. I., as assistant to the chief engineer. He was formerly affiliated with the industrial heating division of Westinghouse Electric Corp. in Meadville, Pa.

John J. Farrell has been named assistant manager, sales promotion and advertising, for Vanadium Corp. of America, New York. For the past three years, he had been a district representative in the company's Chicago office.

Navin Kothari has resigned as plant metallurgist at Dixon Sintaloy, Inc., Stamford, Conn., to join the department of engineering research of North Carolina State College, Raleigh, N. C.

Joseph W. Tackett, formerly at Virginia Polytechnic Institute, has recently been appointed to the staff of the Oak Ridge National Laboratory, Oak Ridge, Tenn.

Walter E. Farrel has been named manager, transformer sales, of the divisional sales section of Federal Pacific Electric Co.'s Pacific Switchgear Div., San Francisco.

C. J. Huffman has been appointed technical specialist in the pig, ingot and billet product office of Kaiser Aluminum & Chemical Sales, Inc. Mr. Huffman, who joined Kaiser Aluminum in 1954, most recently held the post of technical specialist in the extrusions product office in Chicago.

Douglas V. Keller, Jr., has been appointed to the faculty of Montana School of Mines, Butte, Montana, as assistant professor in the department of metallurgy.

Gladstone C. Hill has been appointed manager of sales, St. Paul, of U. S. Steel Corp. Affiliated with U. S. Steel since 1922, Mr. Hill was formerly manager of sales in Indianapolis, Ind.

Personals . . .

William Nelson, employed by Leeds & Northrup Co., Philadelphia, as senior field engineer operating from the Buffalo, N. Y., district office, has been transferred to Leeds & Northrup Canada Ltd., Toronto, as sales supervisor.

Edward C. Nelson, formerly associated with the Dept. of Metallurgical Engineering, Rensselaer Polytechnic Institute, is now at Tonawanda (N. Y.) Research Laboratory of the Linde Co.

John Wambold is now affiliated with Alloy Surfaces Co., Wilmington, Del., as chief metallurgist.

Alex Mich, Jr., formerly senior materials engineer, product engineering, hardware and accessories division, Ford Motor Co., is now assistant examiner for the U. S. Patent Office and is attending George Washington University Law School.

Thomas F. Frangos is now with the Union Carbide International Co. working with licensing and patents in foreign countries. He was formerly engaged in market investigations and promotion of new products for the Haynes Stellite Co., a division of Union Carbide Corp., Kokomo, Ind.

J. C. Heymann is now a project engineer at the Meadville, Pa., plant of National Bearing Div., American Brake Shoe Co.

Wilbur Hering Armacost has been awarded the American Society of Mechanical Engineers Medal given for distinguished service in engineering and science. Mr. Armacost is vice-president–consultant and chairman of the technical committee at Combustion Engineering, Inc., New York.

Otto Ehlers, formerly a design engineer, Industrial Heating Div., Westinghouse Electric Corp., Meadville, Pa., is presently employed by Ipsen Industries, Inc., Rockford, Ill., as an electrical engineer.

I. Kirk Schlamp has been promoted to general manager of the Ravenna Metal Products Div., Seattle, of the Standard Screw Co. Mr. Schlamp, former factory manager, has been with Ravenna for the past 16 years.

Personals . . .

Italo S. Servi, former staff metallurgist at the Metals Research Laboratories, Electro Metallurgical Co., Niagara Falls, N.Y., has assumed a new post with the company in which he will be responsible for fundamental research in the fields of solid-state physics and surface chemistry.

T. L. Russell, who recently received a Ph.D. degree in mechanical engineering at California Institute of Technology, has joined the drilling research group in oil field research at the La Habra Laboratory of California Research Corp., San Francisco, as a research engineer.

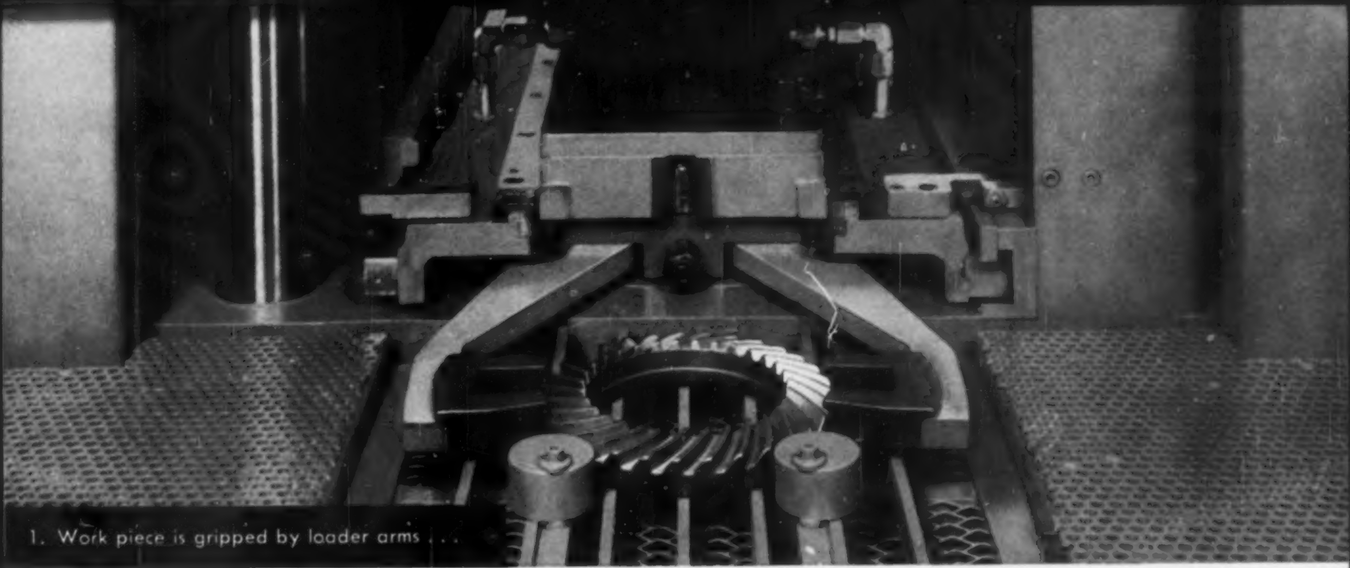
John F. O'Keefe has been transferred from director, electrical and chemical section of Reynolds Metals Co., Richmond, Va., to director, transportation and machinery section, in the Company's product development department.

Charles B. Cobun has been appointed assistant district representative for Heppenstall Co. in its Pittsburgh sales district. Assigned to the Chicago sales district since joining the company in 1951, he was named manager of ring sales, with headquarters in Indianapolis, Ind., two years ago.

Dale J. Richards has been promoted to district manager in charge of the Detroit sales office of the Beryllium Corp., Reading, Pa. Mr. Richards joined the firm in 1953 and until recently held the position of district representative in Detroit.

Madan Nanda has accepted a post as metallurgical associate at Brookhaven National Laboratory, Upton, L. I., N. Y., working with the graphite development group. Prior to joining the laboratory, he was a metals engineer with the semiconductor device development group at Federal Telephone and Radio Co., Clifton, N. J.

Herbert J. Arnold has been appointed assistant product manager of stainless bar, wire and billet products for Crucible Steel Co. of America, Pittsburgh. Since joining Crucible in 1945, he has held various supervisory positions, most recently serving as supervisor of stainless flat rolled product sales.



1. Work piece is gripped by loader arms . . .

2. . . . which move piece to quenching die . . .

3. . . . where controlled flexing relieves strains before quenching.

New Gleason machine quenches gears *3 times faster* with minimum distortion

The unique, fully automatic method incorporated into the new Gleason No. 117 Quenching Machine makes it possible to quench gears and other parts faster than ever before without significant distortion.

The machine discharges a piece every 30 seconds; accommodates 17 pieces in process at one time.

Automatic handling. Once a part is deposited at the front of the machine, the No. 117 positions it on a quenching die and then clamps, flexes, and quenches it. Initial quenching takes only about ten seconds.

When the part cools past the critical hardening temperature, it is released from the dies. Still immersed in oil, the part then cools completely as it travels on a conveyor to the unload chute. As soon as part is released from dies, the machine is ready to receive another work piece.

Flexing before quenching. Each hot part is flexed between the dies to relieve internal stresses. Rate and number of flexes are easily preset. Hydraulic pressure produces positive diaphragming action.

Pulsing. All pressure on the work is pulsed momentarily throughout the die-quench. This permits work to contract without strain. During the die-quench, oil flows uniformly over and around the part.

Faster production. You can speed up production materially with the Gleason No. 117 Quenching Machine. It handles ring gears and cylindrical parts up to 10½" in diameter and 8" high. You can connect it with any conventional furnace so that parts are automatically fed to the quenching press. Push-button controls and timers are adjustable and easy to set. Dies can be changed quickly and easily.

Gleason engineers are ready to help you step up productivity with this new machine. For complete details, write for bulletin.

Gleason No. 117 Quenching Machine

GLEASON WORKS

Builders of bevel gear machinery for over 90 years

1000 UNIVERSITY AVE., ROCHESTER 3, N.Y.

Metals Engineering Digest

. . . Interpretative Reports of World-Wide Developments

Two New Sintering Plants

Digest of "Layout and Design of the Ashland Sintering Plant", by Richard W. Adams, and "J & L's Cleveland Works Sinter Plant", by K. S. Loofboro. Papers presented at A.I.S.E. Convention, Cleveland, September 1958.

A couple of talks presented at the A.I.S.E. Convention in Cleveland discussed the addition of sintering facilities to the Jones & Laughlin Cleveland plant and the Armco Ashland (Ky.) plant. In both instances, the equipment produces sinter for the blast furnaces, but the installations are different.

The Armco sinter plant, built by Dravo Corp., is constructed under Lurgi Co. (Germany) licenses. Built primarily to agglomerate Labrador iron ore, it will also reclaim 16-year-old accumulations of flue dust and sludge. There is an estimated 180,000 tons of iron in the pile, and most of it can be extracted for subsequent use. Generally the plant equipment is similar to that of most sintering plants; ore and flue dust is mixed with fuel, spread over pallets, ignited and fused. Cooling and screening follow. Belts convey materials throughout the plant.

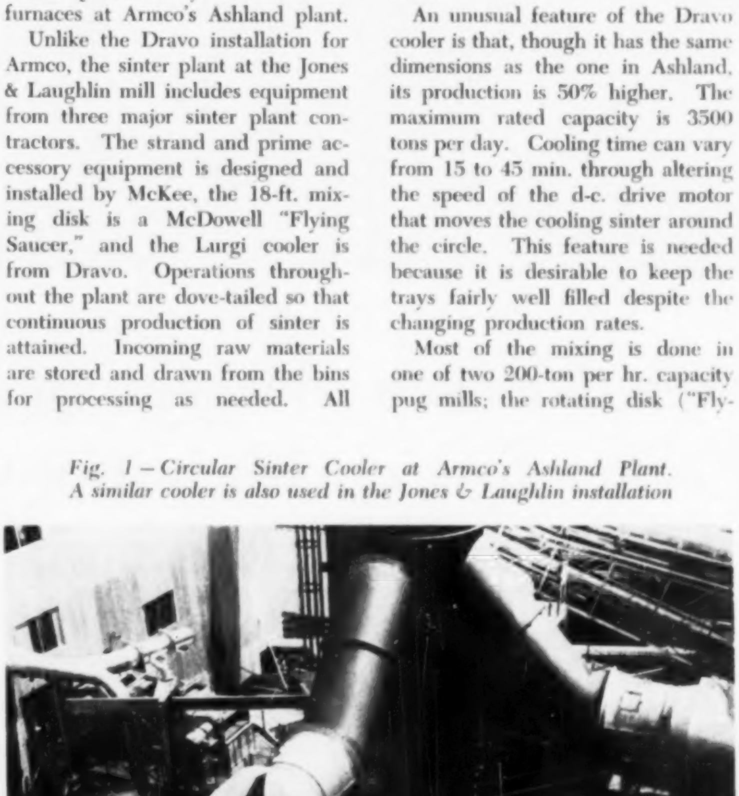
The sinter breaker and sinter cooler have some interesting features. Consisting of a hexagonal shaft with removable hubs and breaker arms, the breaker rotates to force sinter through a series of heavy bars. The arms are of mild steel, hard-surfaced at the tip for wear. The cooler (which cools the newly sintered material) is circular having a diameter of 65 ft. Powered by three fans (see Fig. 1) each with a 150,000 cu.ft. per min. capacity, the cooler can process 2400 tons every day. This sinter will be processed by the three blast furnaces at Armco's Ashland plant.

Unlike the Dravo installation for Armco, the sinter plant at the Jones & Laughlin mill includes equipment from three major sinter plant contractors. The strand and prime accessory equipment is designed and installed by McKee, the 18-ft. mixing disk is a McDowell "Flying Saucer," and the Lurgi cooler is from Dravo. Operations throughout the plant are dove-tailed so that continuous production of sinter is attained. Incoming raw materials are stored and drawn from the bins for processing as needed. All weighing is automatic; the whole process is controlled from a central station.

An unusual feature of the Dravo cooler is that, though it has the same dimensions as the one in Ashland, its production is 50% higher. The maximum rated capacity is 3500 tons per day. Cooling time can vary from 15 to 45 min. through altering the speed of the d-c. drive motor that moves the cooling sinter around the circle. This feature is needed because it is desirable to keep the trays fairly well filled despite the changing production rates.

Most of the mixing is done in one of two 200-ton per hr. capacity pug mills; the rotating disk ("Fly-

Fig. 1 – Circular Sinter Cooler at Armco's Ashland Plant. A similar cooler is also used in the Jones & Laughlin installation



Sintering Plants . . .

ing Saucer") is a stand-by and is mainly intended for future experimental work. Any combination of pug mills and disk can be used to prepare the mix.

Troubles have occurred during operation of this sinter plant. Cracked frames on many of the pallets have caused binding of the strand and shearing of drive pins. Grate bars, formerly in two sections, were not satisfactory and are being replaced by single-section bars. Though the hot screen operated without any trouble, two more are being added for increased efficiency. The sinter fan must be run at reduced speed until waste gas temperature is above the dew point. Otherwise a build-up can occur on the blade and cause undesirable vibration. The structural work holding the cooler 20 ft. above the ground had to be strengthened to eliminate vibrations. Belt meters, which maintain a balanced mixture on the strand, can be damaged by overweight. All cells should be enclosed and dust accumulations removed regularly. At some belt transfer points, especially those for incoming raw materials, pile-ups are frequent.

Despite these difficulties, the plant operates well and has exceeded its designed rate of 2500 tons a day.

C.R.W.

Castable and Plastic Refractories

Digest of "Monolithic Refractory Constructions in Steel Plant Equipment — Plastic and Castable Refractories Compared", by G. D. Cobaugh and C. R. Hauth. Paper presented at A.I.S.E. Convention, Cleveland, September 1958.

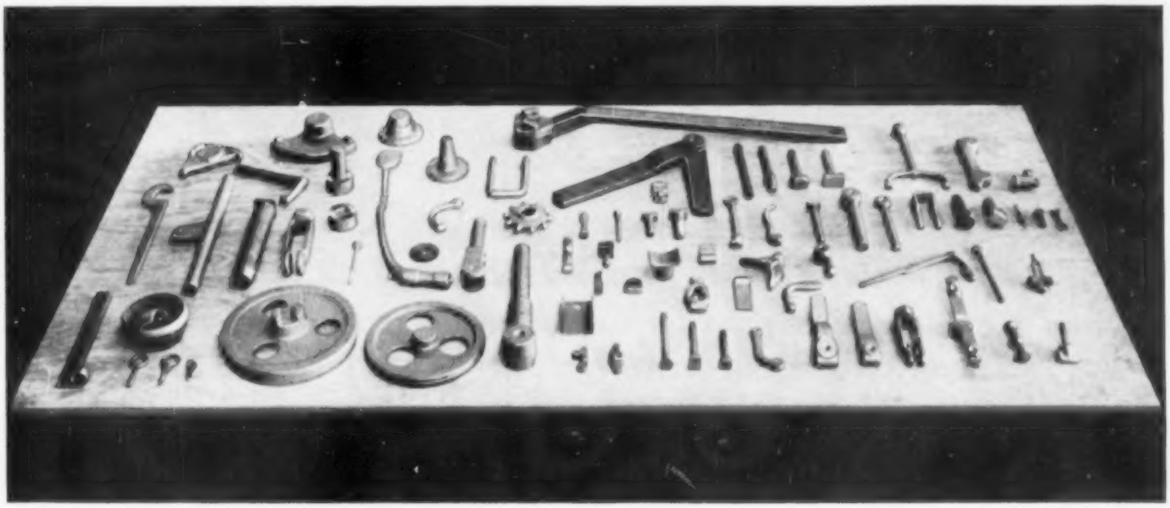
Two types of monolithic refractories, castable and plastic, are being used in steel mill furnaces today. They offer ease of maintenance and good service life at reasonable cost.

Castable refractories are shipped in bags and mixed at the furnace site, then poured or tamped into place. The various grades weigh from 25 to 170 lb. per cu.ft.; they can be used for applications up to 3000° F. Panel construction is

200 Different Parts Heated for Forging -

Better, Faster and at Much Lower Cost

with TOCCO* *Induction Heating*



• When progressive production people at General Railway Signal Company installed a 200 kw, 3000 cycle TOCCO machine, they were able to eliminate 7 slot-type oil-fired furnaces and produce better forging than ever before—at substantially lower costs.

Cost Down—Fuel costs have been reduced from $15.26 to $1.60 per hour with TOCCO. Expensive furnace lining maintenance has been eliminated, and straightening and reheating operations formerly required are no longer necessary.

With oil-fired furnaces all steam hammer operators needed helpers. With TOCCO most of these helper operations have been eliminated.

TOCCO's fast, automatic operation produces almost no scale and achieves uniform temperatures throughout the entire cross section—improving the quality of the forgings and providing increases of up to 400% in the life of the forging dies.

Overall production costs in the forge shop at G.R.S. have been reduced an impressive 35%!

Flexibility—Production runs at G.R.S. range from a low of 15 pieces to a high of over 50,000. Parts from ½ pound to over 25 pounds are heated, merely by changing inductor coils and power control settings.

Better Working Conditions—TOCCO makes the forge shop a better place to work by doing away with noise, dust, dirt, smoke and radiant heat and gases produced by old fashioned furnaces.

If you're looking for a way to produce similar results in your plant, it will pay you to consult a TOCCO Engineer.

TOCCO

JUST PUSH A BUTTON

*Trade Mark Reg. U. S. Pat. Off.

THE OHIO CRANKSHAFT COMPANY

Mail Coupon Today—NEW FREE Bulletin

The Ohio Crankshaft Co. • Dept: R-11, Cleveland 5, Ohio

Please send copy of "Typical Results of TOCCO Induction Heating for Forming and Forging".

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Position______________________

Company______________________

Address______________________

City______________ Zone_____ State__________

Refractories . . .

gaining favor since panels can be cast, cured and dried in a convenient area, and installed as a complete unit.

Plastic refractories are composed of selected calcined and bond clays carefully blended with enough water to ensure proper plastic consistency for ramming or pounding into place. They weigh about 135 lb. per cu.ft., and have a service limit of 3100° F. Particularly useful for patching and emergency repairs, they have been applied to entire structures, and have given excellent service. Plastic serves best at high temperatures where a ceramic bond will form in the hot face; at lower temperatures, castables give better service in most instances.

Monolithic refractories are being adapted for several applications. Among these are blast furnace bosh and inwall cooler linings and soaking pit walls and covers. In both instances, operating economies and good performance are offered.

C.R.W.

Developments in Hot Strip Mills

Digest of "Recent Developments in Design and Control of Hot Strip Mills", by R. W. Barnitz and H. H. Shakely. Paper presented at the A.I.S.E. Convention, Cleveland, September 1958.

In the last few years, design of new strip mills has been aimed at keeping equipment and installation costs down. At the Aliquippa Works of Jones & Laughlin Steel Corp., these efforts had to be coupled with a need for increased efficiency and problems arising from lack of space. Consequently, a reversing roughing mill was suggested to replace four roughing stands. By having one stand do the work of several, it was possible to lower costs. Further, the coil size could be increased and, with electrical controls, fast, continuous operation could be accomplished.

Similar improvements were made at Jones & Laughlin's Cleveland plant, too. In addition, operating functions were completely programed through an IBM punch-

Hot Strip Mills . . .

card system. Information for rolling up to nine passes is punched including scale breaker, mill and edger openings. Mill and table directions, and speeds are programed along with necessary draft compensations. All the operator needs to do is press two buttons, the Schedule Advance which reads the information from the card, and Pass Advance which starts the mill. Subsequent operation is automatic. The screws return to original settings after the last pass. Semiautomatic and manual operations are also possible.

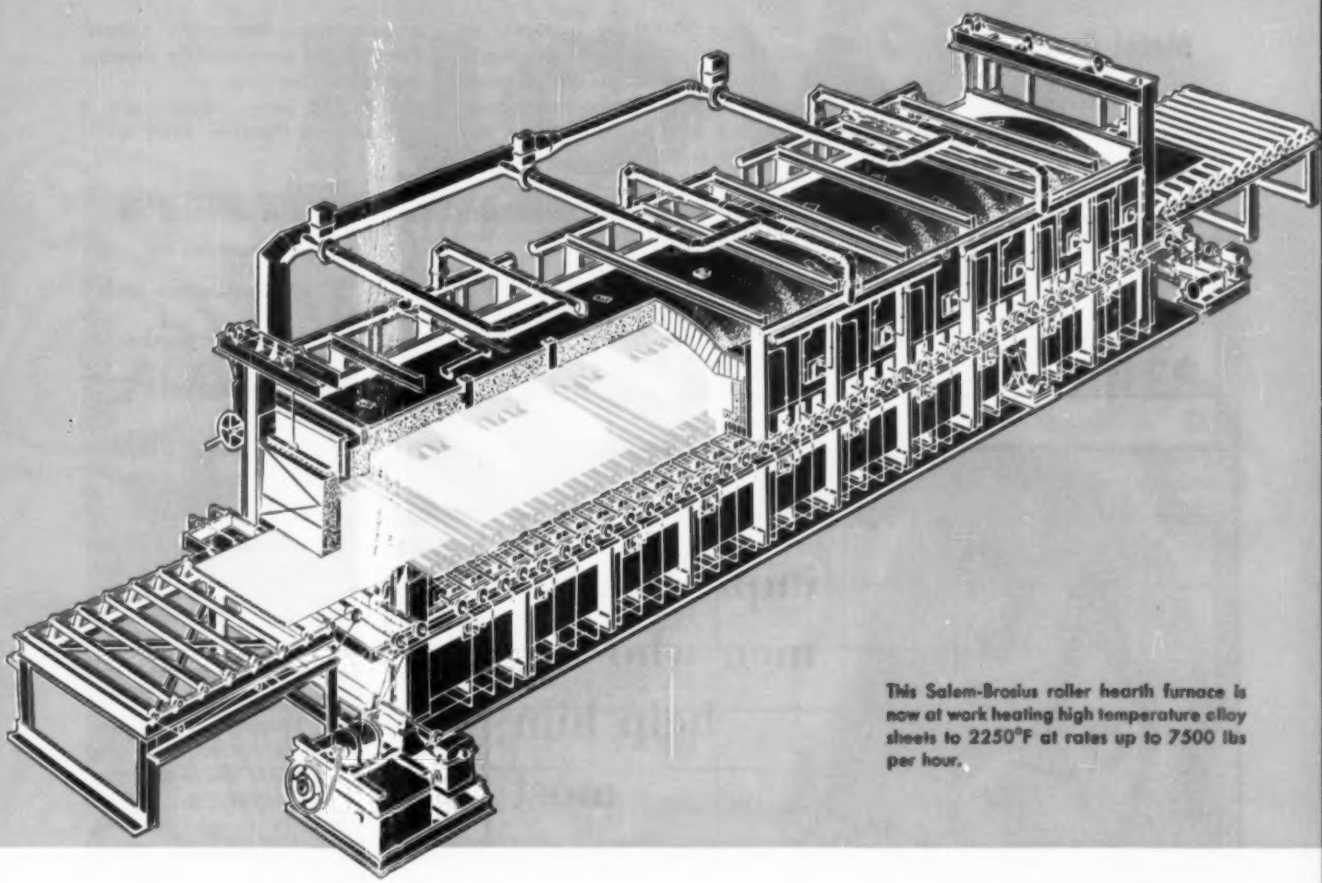
Each operation is so timed that the mill is in motion almost constantly. As one operation ends, tables and screw settings are adjusting automatically to positions required for the next operation. During initiation of this new equipment, some troubles were encountered. One difficulty was in determining when steel was out of the mill so that the next ingot could be started. A hot metal detector (optical type) is now used; it gives an adequate signal but a better method is still desired. Short stroke controls of side guards and verticals, accomplished by slip clutches, brakes and limit switches, has caused considerable delay. Lubrication problems have been solved by specially designed automatic oilers. C.R.W.

Rolling Metal Powder Into Strip

Digest of "Perfected and Practical Methods of Processing Powder Into Commercial Strip", by Richard A. Smucker. Paper presented at A.I.S.E. Convention, Cleveland, September 1958.

COPPER AND NICKEL POWDERS can be rolled into strip on a commercial basis. The powder is fed continuously from a hopper into a gap between turning rolls of a "compacting mill." As the roll-compacted green strip leaves this mill, it is conveyed through a furnace for sintering and subsequent hot rolling. Finally, the strip is coiled under tension after cooling to room temperature. Figure 1 gives a schematic view of the process.

The compacting mill requires rolls specially designed to exert



This Salem-Brosius roller hearth furnace is now at work heating high temperature alloy sheets to 2250°F at rates up to 7500 lbs per hour.

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Steel, brass, nickel, aluminum and other metals in sheets, plate, flat bars, tubes—even trays of small parts—are heated in this type of furnace. In the typical furnace shown above, sizes of slabs and plates heated range from 40 x 71 inches to 58 x 95 inches.

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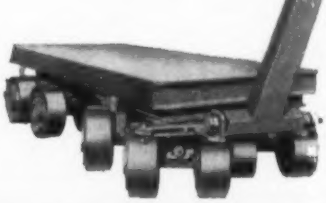

Salem-Brosius heavy-duty trailers (left) are ideal for handling in-plant loads of the same type of materials that are heated in the furnace shown above. Phil-Dumps—as shown at the right—are well suited to the handling, automatic dumping and storing of parts and bulk materials. They handle easily with a fork or platform lift truck.

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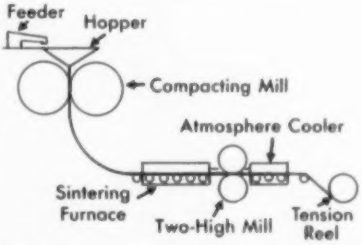
Metal Powder . . .

equal pressures throughout the strip width; edges must also be uniformly and tightly compacted. Maximum compact thickness is a function of roll diameter; for 11-in. diameter rolls, maximum thickness is 0.050 to 0.060 in., depending on the powder. Lubricants which aid compacting include kerosene and low-pressure steam. Pressures may vary from 60,000 psi. (copper) to 120,000 psi. (some nickel powders).

A roller hearth, gas-fired furnace is suitable for sintering many compacts. A tapered enclosure at the discharge end of the sinter section helps maintain heat in the strip to aid hot rolling. This snout also keeps the strip surrounded by the sinter atmosphere, which is important. A conventional hot mill modified by external heaters and internal cooling does the rolling. Cooling in a protective atmosphere follows. Processing is completed by shearing and rolling the strip.

With this setup, copper coils, 6 in. wide and 0.050 in. thick, could



Continuous Process for Converting Metal Powder Into Strip

be produced at rates of 6 ft. per min. Experimenal coils, annealed and cold rolled to 0.010 in., were tested at 39,450 to 41,000 psi. tensile strength with 26.9 to 34.7% elong. These values compared favorably with those of conventional electrolytic annealed copper strip of like dimensions. Chemical analyses also showed that the sintered strip contained considerably less oxygen than did similar electrolytic strip.

While most of the work has been done with copper powder, it is thought that this process opens the way to production of special alloy strip. Problems resulting from the high sintering temperatures which will be required will have to be solved. C.R.W.

Quality Control of Nonferrous Castings

Digest of Symposium on "Metallurgical Aspects of the Control of Quality in Nonferrous Castings", *Journal*, Institute of Metals, Vol. 85, February, March and April 1957.

THIS SYMPOSIUM provides a reference source of value to all those engaged in the production of castings, because a large amount of pertinent data has been collected by those whose experience enables them to separate the wheat from the chaff.

"The Role of Statistical Methods in Controlling the Quality of Nonferrous Castings", by A. R. Martin, February, p. 209-226 – This is a rather complete description of the development and use of statistical methods. The author himself states

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4427	0.24/0.29	0.70/0.90	0.040	0.040	0.20/0.35	---	---	0.35/0.45	4427
4520	0.18/0.23	0.45/0.65	0.040	0.040	0.20/0.35	---	---	0.45/0.60	4520
4718	0.16/0.21	0.70/0.90	0.040	0.040	0.20/0.35	0.90/1.20	0.35/0.55	0.30/0.40	4718
8822	0.20/0.25	0.75/1.00	0.040	0.040	0.20/0.35	0.40/0.70	0.40/0.60	0.30/0.40	8822

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Quality Control . . .

in the subsequent discussion that "the direct application of statistical methods to the control of quality castings is severely limited . . ." The three methods used are the Binomial, Gaussian, and Poisson distribution. The Gaussian method is the one most widely employed. Those whose interest is mainly in the theoretical methematical approach to foundry work should study the paper fully.

"Metallurgical Control of Quality in the Production of Aluminum Alloy Castings", by A. V. Carless, February, p. 227-235 – British nomenclature is used in all the papers of this symposium. The main alloys used

Fig. 1 – Sections Cut Through Gas Test Specimens Showing Gross Porosity, Porosity During Degassing, and Sample From Same Melt 5 Min. After Completion of Operation

without heat treatment are LM 4 and LM 6. The former contains 3% Cu, 5% Si, and 0.4% Mn with controlled amounts of certain other elements including magnesium up to 0.15%. The latter contains about 12% Si. In heat treated condition, alloys LM 10-W, and LM 11-W are used, the former containing 4.5%

Cu and the latter 10.5% Mg.

The need is stressed for cleanliness of furnace tools, and careful lining or coating of all pots. Fast-drying paint is used for identifying all the various alloys, gates and sprues. For melting, plumbago crucibles are preferred to steel pots to avoid iron pickup, especially for high-silicon and magnesium alloys.

In controlling melting practice, the main concern is gas pickup – the gas being almost entirely hydrogen. Several sources of pickup are mentioned: (*a*) careless storing of metal resulting in surface corrosion products, (*b*) impingement of furnace gases (inert cover flux is used to prevent this), and (*c*) pickup from melting pots and tools which have not been heated enough to eliminate moisture in hydrated material.

Hexachlorethane in tablet form is used as a degasifier. To ensure that the metal has a low gas content, a sample of the molten metal is placed in a small autoclave and allowed to solidify under reduced pressure. The cooling is watched through a suitable window. Unduly high gas content is apparent from the appearance of a swollen, convex surface, caused by the upward pressure of the dissolved gas. Figure 1 shows the progress of degassing in a gas-test specimen. Grain is refined by adding titanium boride. As to temperature control, the metal should be heated as little above its melting point consistent with the hiatus between removal from melting pot and casting into the mold. In a brief manner, gating, feeding and metal-mold reaction are discussed.

"The Control of Quality of Magnesium-Base Alloy Castings", by E. F. Emley and P. A. Fisher, February, p. 236-254 – The paper discusses sand and gravity die castings, and considers three aspects of control, namely, practical steps necessary to obtain high quality, routine inspection of the castings obtained, and determination of origin of defects. The alloys fall roughly into two groups, the one containing zirconium, the other aluminum.

Alloys containing zirconium constitute the major proportion of magnesium castings for aircraft usage in Great Britain. Zirconium is effective in refining the grain and improving the mechanical properties.

(*Continued on p.* 150)

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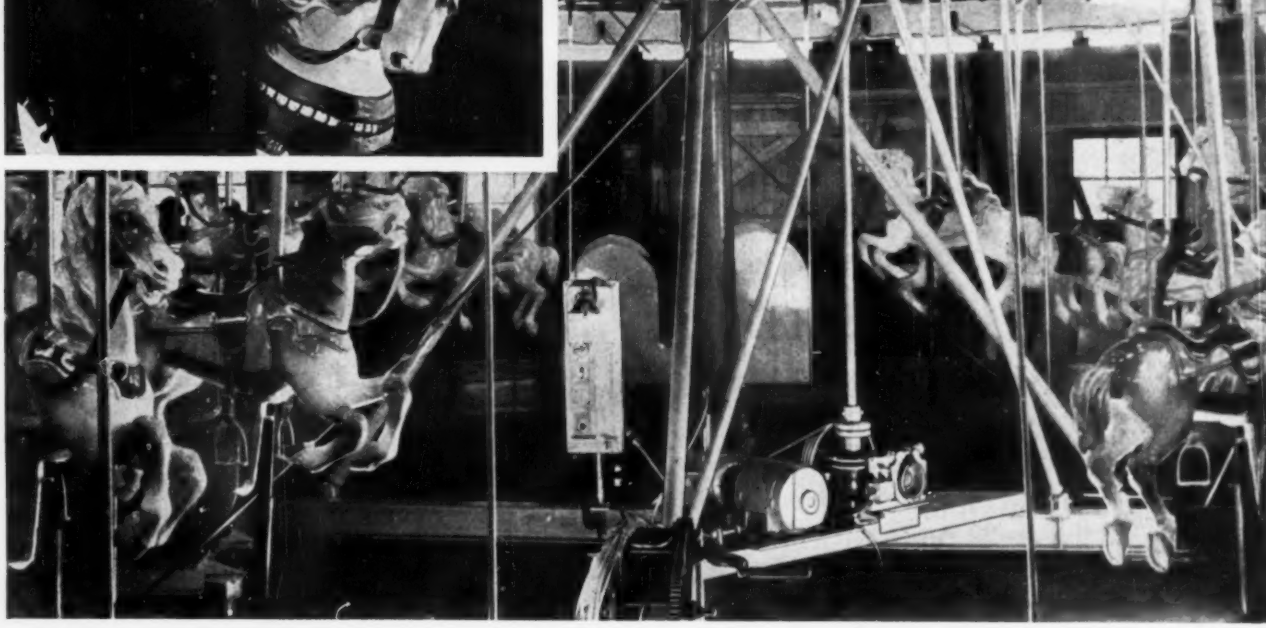

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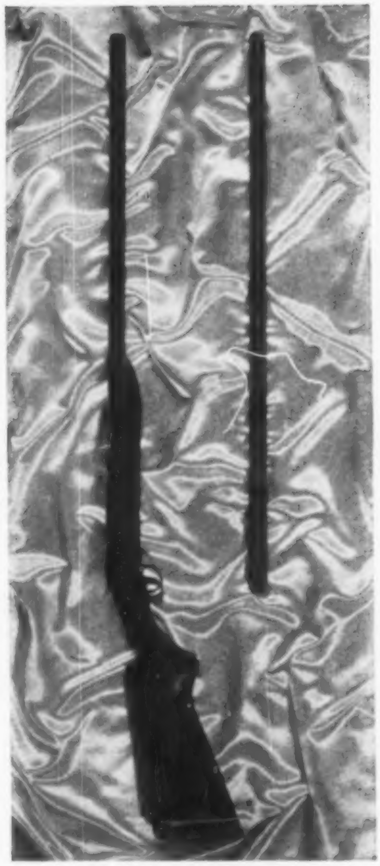

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Quality Control . . .

Its solubility is limited to 0.6% to 0.8%. Zirconium content is reduced on melting by precipitating the undissolved portion from solution by aluminum, silicon, iron, manganese, carbon and hydrogen. Zirconium is introduced via proprietary salt mixtures containing ZrF_4 or $ZrCl_4$ or by master alloys. There are two groups of zirconium alloys, the high strength and the high temperature. The former owe their high strength to zinc, and the latter their creep resistance at high temperature to rare earth metals and thorium. When thorium is used, oxidation losses are minimized with a flux. Thorium is normally added as a hardener alloy with magnesium, containing 20% Th and 2.25% Zn.

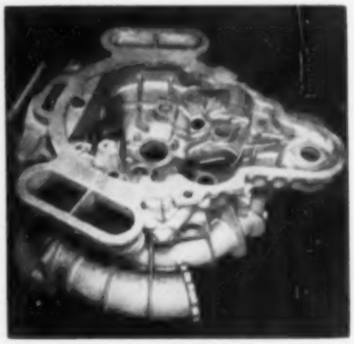

Fig. 2 – Aircraft Supercharger Casting Weighing Approximately 350 Lb. and Incorporating More Than 50 Cores

The aluminum group contains zinc and a small amount of manganese. The manganese is to increase corrosion resistance and to offset the effect of iron. Grain size is controlled by some form of carbon inoculation treatment, or by superheating the melt for a period to temperatures above 1560° F.

Emphasis is placed on the need for careful pouring and the use of sulphur for control of casting quality. Molding sand is appraised; silica sand and bentonite with 2 to 3% moisture is recommended. The abstractor is surprised to find that "a good indication of moisture content can be obtained by feel", although periodic checks are also recommended. Ramming, venting and skin drying are discussed.

Manganese castings are suited to

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Quality Control . . .

shell molding. Blue surface mottling is due to inverse segregation caused by Mg_2Si which occurs in magnesium-aluminum alloys.

The latter part of the paper deals with gravity die castings. The production of sound castings is said to depend upon correct design, operating temperature, die dressing, metal temperature, method of filling the mold and stripping. Sand castings include some of the most complex shapes ever attempted. An example is the aircraft supercharger casing shown in Fig. 2. Much of the advice given for sand castings is also applicable to die casting. Among the physical data given is the elongation of these alloys which in some instances amounts to 310%.

"The Metallurgical Principles of the Control of Quality of Nonferrous Castings", by R. W. Ruddle and A. Cibula, March, p. 265-292 – This paper deals with sand castings. There are three main divisions:

1. The flow of liquid metals through the gating system, and during the filling of the mold.
2. The mechanism of freezing involving heat flow in the casting and the mold, feeding, segregation, grain refinement, and hot tearing.
3. Control of gas content and grain size, and the avoidance of the presence of nonmetallic inclusions.

Any gating system must aim at giving the minimum of agitation especially for alloys of aluminum or magnesium. Brasses, gun metal and bronzes are less affected, and high-content phosphor alloys still less. As to sprues, it should be remembered that even if the pouring rate is high enough to enable the entrance to a parallel sprue to be filled, the stream of metal contracts and separates from the mold wall as it gains speed in falling, and splashing occurs. These effects are made worse by the aspiration of air through the mold wall, which leads to continual entrainment of air.

Pouring basins, tapered sprues, runners, dross traps, are all discussed. Gates and gating ratios are described in considerable detail, accompanied by numerous sketches. Also rate of flow and filling of the mold cavity are discussed in detail. The matter of heat extraction and freezing rates in castings is care-

fully considered from a mathematical viewpoint. A table is given for the mold constants of various molding materials. To promote feeding, the author refers to a recent invention that involves placing of a capsule containing a gas-generating substance in the top of a blind riser. When the molten metal fires the capsule, the evolved gas forces liquid into the casting under pressure substantially higher than the atmosphere.

Some alloying additions have an appreciable influence on hydrogen solubility. Tin bronzes containing zinc only need 0.03% P to cause mold reaction, while bronzes without zinc require 0.30%. The Ransley gas tester presently used with aluminum alloys is said to be adaptable to bronzes to ascertain their hydrogen content.

"The Metallurgical Control of Quality in the Production of Copper-Base Alloy Castings", by A. R. French, March, p. 293-317 – Some eighteen constitution diagrams are given, and discussed in this paper. These cover brasses and bronzes of a very considerable range. Then follows the influence of basic composition and microstructure.

A tabulation of particular interest compares the leaded and lead-free gun metals and the phosphor bronzes. If the results have been derived from a sufficiently large number of tests, they are of the utmost importance to all those engaged in the production of castings that have to be pressure tight after machining. It is also an argument in favor of gas-free metal as opposed to the theory that a little gas helps in the more uniform distribution of the gas present. Incidentally, the author points out that silicon content brasses have replaced tin bronzes in the U.S.S.R..

The next section deals with the influence of impurities other than reducing gases, followed by a summary of recent work relating to the influence of reducing gases.

In discussing foundry practice, the author is of the opinion that if virgin metals are used, with the current melting and alloying technique, there is no reason why metal should not be poured directly without pre-ingotting. It is claimed that zinc content in high-tensile brasses can be controlled to within 0.5%. The paper concludes with a discussion

of the chill casting of copper-tin alloys, high-tensile brasses, and aluminum bronzes.

"The Control of Quality in the Production of Nickel Alloy Sand Castings", by D. R. Wood and J. F. Gregg, March, p. 319-329 – The importance of carbon content is emphasized. Relatively small variations have marked effects on the structure and properties of nickel alloys. At room temperature the carbon solubility of pure nickel is 0.20%. Alloying of nickel reduces the solubility of carbon so that for Monel, containing 30% Cu and 4% Si, free graphite appears at 0.10% C. The addition of magnesium will spherodize this carbon as shown in the micrograph in Fig. 3. Sulphur forms a eutectic with nickel at 21.5% S. Columbium definitely improves weldability up to 2%, as also does the treatment of the molten metal with gaseous oxygen. Owing to the high temperatures required for nickel alloys (2640 to 2910° F.), coreless induction, direct-arc, and high-frequency induction furnaces are used with either acid or basic linings, the latter being preferred. A description is given of boiling to eliminate hydrogen. Crushed graph-

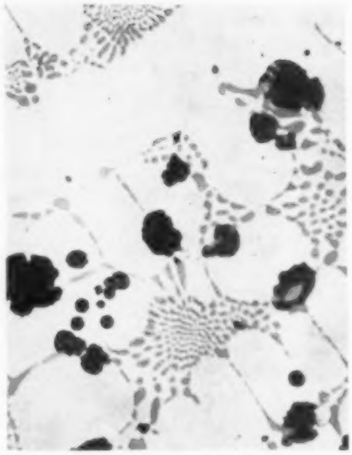

Fig. 3 – A Nickel-Carbon Alloy Containing Magnesium and Showing Nodular Graphite. 200 ×

ite (0.1%) and black nickel oxide (0.5%) are mixed and added to the charge. Magnesium or calcium silicide is used for deoxidation and desulphurization. A table given shows the result of oxygen lancing the molten metal. Phosphorus, silicon, manganese, and chromium contents were significantly reduced, but sulphur was unaffected. The author recommends that temperatures should be taken with platinum, platinum-rhodium couples protected by a thin-walled silica sheath.

"The Control of Quality of Pressure Die Castings", by H. J. Sharp, March, p. 330-338 – The majority of pressure die castings are produced from zinc or aluminum-base alloys, although some magnesium is cast using this technique. The highest purity of metal must be maintained. The Hilger medium quartz spectograph is usually adopted to control quality. It is specialized and demands constant attention to detail. A direct method of quality control – but more time consuming – is steam testing. Die-cast tensile specimens or actual castings are exposed to water vapor 95° C. (200° F.) and 1 atm. for 10 days, then examined for growth and mechanical properties.

The question of the design both of the casting and the die are of paramount importance with special reference to thermal balance in the die. The die must be filled in 0.2 sec. or less. The author also reviews injection pressure techniques and discusses new approaches, as well.

H. J. Roast

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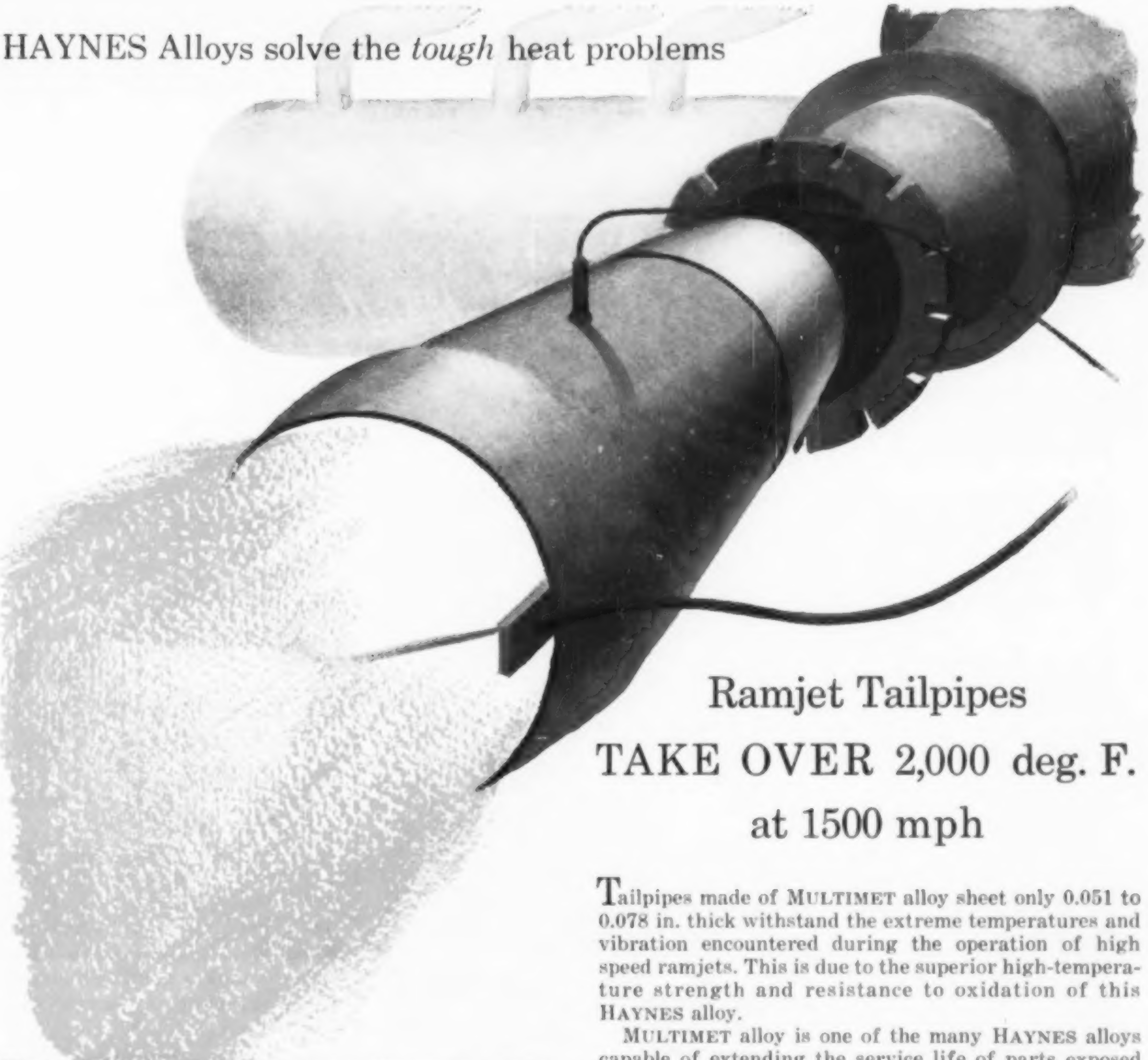

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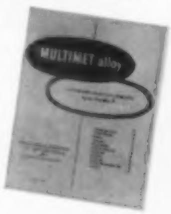

Ramjet tailpipes are formed from MULTIMET alloy sheet in four sections. The entire assembly is over 2 ft. in diameter at the large end and nearly seven ft. long.

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Nondestructive Tests for Nonferrous Castings

Digest of "Non-Destructive Testing in the Control of Quality of Non-Ferrous Castings", by S. L. Fry, *Journal* of the Institute of Metals, April 1957, Vol. 85, p. 361-366.

INCREASED AVAILABILITY of nondestructive methods of testing has resulted in a marked increase in the use of castings. Many present-day applications involve highly stressed castings which require critical examination.

The methods of nondestructive testing suitable for present-day castings are visual inspection, use of liquid penetrant for surface and subsurface discontinuities, pressure testing, and ultrasonic and radiographic examination.

Careful visual examination of a casting before and after cleaning may reveal cold shuts, blows and cracks; this method should always be used before employing other means of nondestructive testing.

Penetration methods depend on the introduction of a suitable liquid containing a dye into the pores and cracks of a casting. After removal of surplus dye, the casting is allowed to stand, and seepage of the liquid from cracks reveals their location. Greater sensitivity is achieved by the use of a fine developing powder which draws the dye from the void through capillary action, thus giving more positive identification of defects. The penetrant can either be a brightly colored liquid or a fluorescent material. The castings must be degreased.

Castings for high-pressure applications should be pressure tested. The method of test is simple. All possible exits are blocked and air, oil or water is admitted under pressure. If any leaks show, the areas are suitably marked.

Although ultrasonics are used extensively for inspection of cast billets, which are uncomplicated in shape, this method has found little application for castings of more intricate configuration.

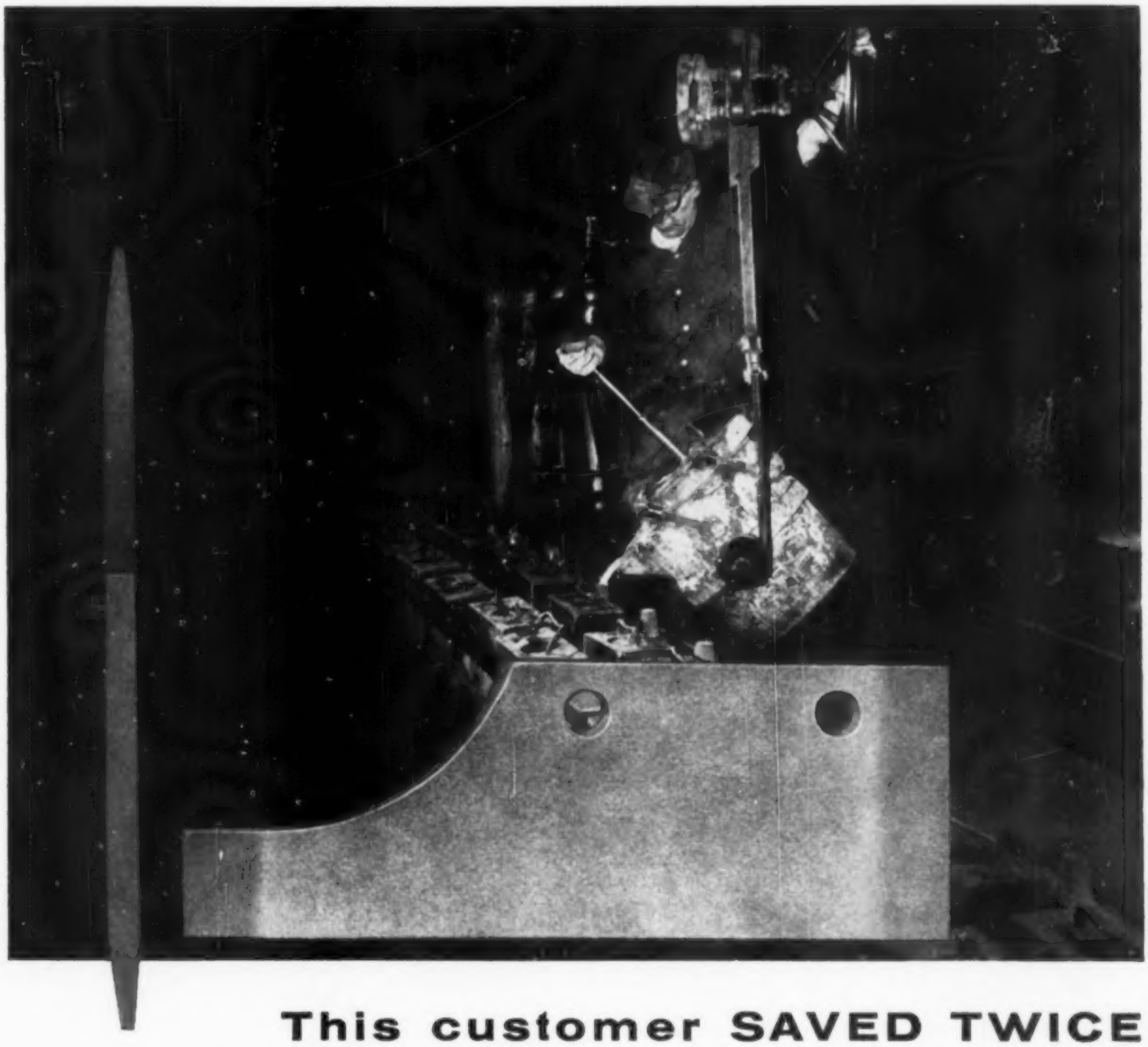
In fluoroscopy, applicable only to light alloy castings, radiation from an X-ray tube passes through the part and then falls on a fluorescent screen where it excites an image of the casting that can be directly observed in a darkened room. This makes possible a rapid examination. Screening, however, reveals only gross defects.

Radiographic examination is at present the most important method of nondestructive testing of castings since it yields more information than any other about the type, size and location of internal defects.

Instead of using X-ray equipment, it is now possible to employ radioactive isotopes. Although of little use for light alloys, isotopes have broadened the scope of radiography. However, their radioactivity gradually decreases, as indicated by the term "half-life". Cobalt-60 is the most powerful isotope available commercially, capable of penetrating up to 9 in. of thickness of a dense material such as bronze.

The method of taking radiographs with an isotope is similar to that employed for X-raying. High-contrast film is generally used.

The two main factors which de-



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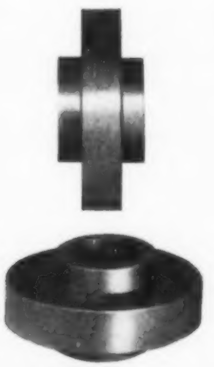
In the wear strip above, shell-cast of Ampco Metal, all dimensions including end-bevels and hole locations were held to ±.015. The smooth surface finish required no machining. Substantial savings of time and money were realized.

With Ampco Shell Moldings, castings can be held to extremely favorable tolerances. Finishing operations are often eliminated; less metal is wasted. More of the tough outer cast shell is retained, providing longer service life.

Casting detail is excellent — oil grooves, deep pockets, and recesses can be cast in, and coring is close and precise, for complex designs impractical by other methods. High production rates reduce molding costs.

Ampco Shell Moldings are available in an extremely wide range of copper-base alloys. Ask an Ampco field engineer to tell you more about this money-saving production process. And write for Bulletin G36-957. *Ampco Metal, Inc., Dept. 20K, Milwaukee 46, Wisconsin. (West Coast Plant: Burbank, Calif.—Southwest: Dallas (Garland County), Texas)*



Gear blank shell-cast in Ampco-loy nickel bronze. Surface finish was held to ± .015. Only finishing required was to hob teeth and broach key-way. Savings were considerable.

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Nondestructive Tests . . .

termine the quality of a radiograph are linear resolution and contrast. Loss of contrast is often the result of scattering of the X-rays. This can be reduced by the use of metal filters and lead backing of films. Radiation from isotopes is characterized by shorter wave lengths, which minimize scatter, a decided practical advantage.

The development of correct radiographic procedures is important, and a number of techniques are described, such as determining sensitivity with a penetrameter, or using wires to measure resolution.

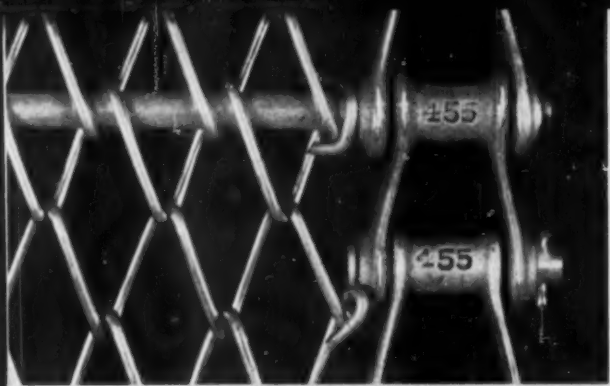
Interpretation can be based on experience only. This is obtained through sectioning of castings and close liaison with the foundry. In some cases, peculiar defective conditions cannot be positively identified.

Major defects revealed by radiography include gas porosity, microshrinkage, segregation, gross inclusions and cracks. For alloys likely to contain fine microshrinkage, the highest resolution possible should be employed, and the highest contrast allowed in the final radiograph.

Gas porosity, unless very severe, does not reduce the mechanical properties appreciably, and the castings exhibiting this condition will very often be pressure-tight. Impregnation successfully treats this type of defect.

Oxide inclusions and blows often are the result of poorly designed gating systems and may be caused by excessive turbulence. The effects of circular defects are easy to chart since the loss of effective section thickness is proportional to their size. Dense and hard inclusions may cause machining difficulties.

To maintain quality, records must be kept. Statistical quality control procedures are a powerful metallurgical tool. Good liaison between the foundry and the testing department is equally important. In some instances, it may be helpful to define the exact position of a defect, and when it is impossible to take shots in two planes, stereoradiographic techniques may be resorted to by moving the X-ray tube to a certain definite distance after an exposure and then making another one, both images being recorded on the same film. The image shift is subsequently



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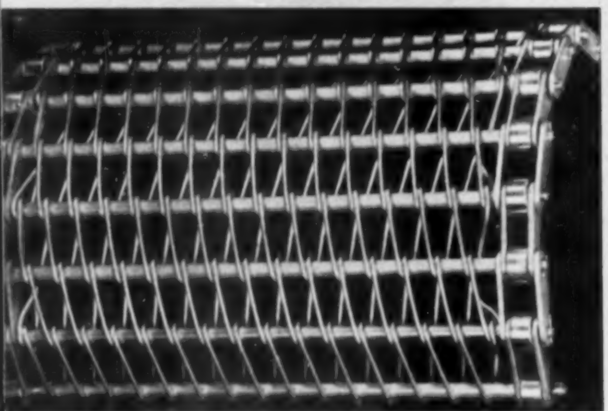

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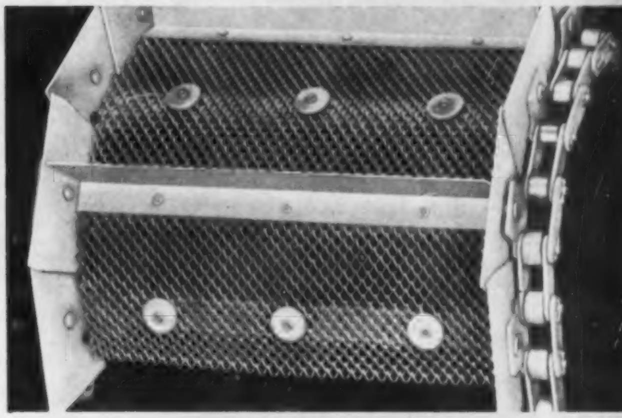

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Nondestructive Tests . . .

measured, and by the use of geometry the distance of the defect from the surface can be fixed.

The author closes by expressing the hope that developments in nondestructive testing techniques will take place in the field of ultrasonic testing, since this method holds the greatest promise of increased speed at reduced costs. HANS HEINE

Measuring Intergranular Corrosion Electrically

Digest of "A Nondestructive Test for Intergranular Corrosion in Stainless Steel Tubing", by R. C. Robinson, E. I. du Pont de Nemours & Co., A.E.C. Research and Development Report DP-153, March 1956, 15 p.

CERTAIN AUSTENITIC STEELS are metallurgically unstable when heated in the temperature range of 425 to 875° C. (800 to 1600° F.). Heating in this temperature range causes chromium carbides to precipitate in the grain boundaries. The metal thus becomes subject to severe intergranular attack by even mildly corrosive liquids. In severe cases the steel may disintegrate into separate grains. This paper describes the development of an electrical instrument for detecting and evaluating this condition in service without damage to the material.

Since intergranular corrosion normally consists of a network of fine cracks or precipitated carbides along the grain boundaries, it is reasonable to expect the electrical resistance of corroded material to be different from that of sound material. To confirm this relationship, five samples of 18-8 Cr-Ni stainless tubing (0.22 in. ID and 0.405 in. OD) possessing varying degrees of intergranular corrosion were checked with respect to their electrical resistance using a Kelvin Bridge. The results of these measurements indicated that the electrical resistance of severely corroded specimens was approximately three to four times greater than the resistance of the completely sound or uncorroded specimens. Since the material to be tested in service consisted of an electrically closed loop of similar tubing, the use of the

(*Continued on p.* 174)

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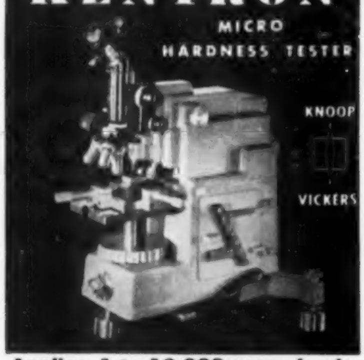

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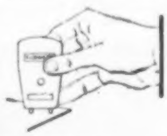

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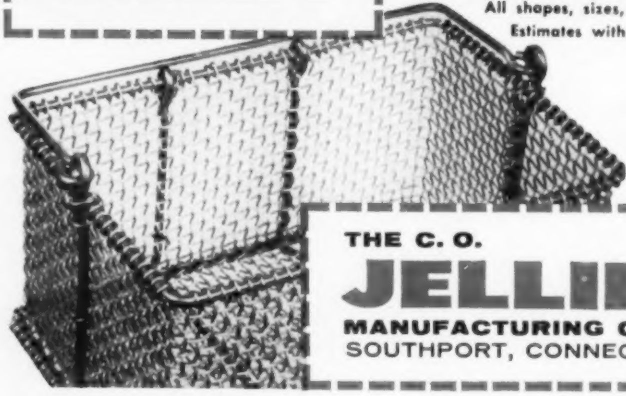

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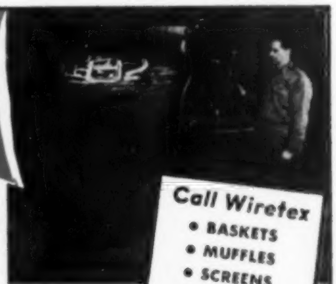
WIRETEX Pit Furnace ASSEMBLY



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A well known foundry customer* substituted **WIRETEX** Inconel baskets and frames for cast iron pots and carriers for their pit type heat treating furnaces and discovered a way to save hundreds of dollars in labor, materials, maintenance and replacements. Best of all . . . production skyrocketed!

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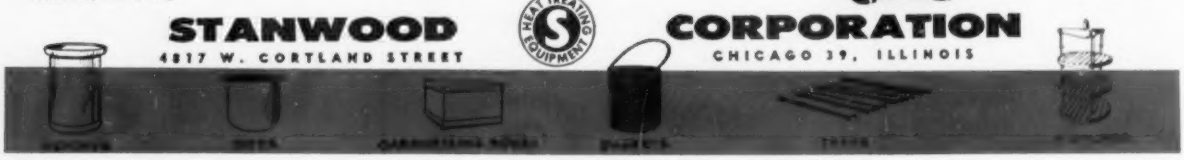

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Corrosion . . .

(Starts on p. 160)

Kelvin Bridge for field test purposes was not considered practicable. The resistance measurements indicated, however, that eddy current measurements might provide a feasible approach to the problem.

In the instrument devised for these measurements, the sensing element was the coil of an oscillator circuit. When the coil, or probe, was placed upon a sample of tubing, eddy currents were induced in the sample at the expense of energy from the oscillator circuit. The induced eddy currents produced an opposing magnetic field that altered the impedance of the probe. The amplitude of the oscillation is thus a function of the electrical conductivity in the sample. If all samples were dimensionally alike, and the probe-to-sample geometry uniform, reliable results could be obtained.

It was concluded that the test instrument possessed the required sensitivity to distinguish a very slightly corroded tube from a sound tube. Furthermore, by means of a variable resistance, it was possible to adjust the sensitivity of the instrument to distinguish between a wide variety of intensities of intergranular corrosion. W. W. AUSTIN

Basic Electric Furnace Refractories

Digest of "Canadian Basic Refractory Practice in Electric Furnaces", by A. H. Thomson, A.I.M.E. Preprint, December 1957, 5 p. Paper presented at the Electric Furnace Steel Conference, Pittsburgh.

THE USE of Canadian-made basic refractories for electric furnaces dates back as far as 1923. At that time a type of dead-burned grain magnesite was being produced from native magnesite at Kilmar, Que., and used with success in openhearth and electric steel furnaces for fettling purposes. This product was the only basic refractory made in Canada up to 1934.

As a result of intensive research and development, Canada produced the first cold setting rammed-bottom material in 1934. Here at last was a product that did not have to be

"burned in" in thin layers. In a relatively short time, this product was being used by all Canadian steel plants and was being shipped to major United States and European consumers as well.

Another material, a refractory plastic first used to line tapholes in open-hearths, was excellent for spouts, patching slag lines, and filling up deep holes in the bottom. As a ladle lining, it performed well with carbon steel or alloys, but was a spectacular success when used in ladles holding manganese steel, where it would last from 60 to 80 heats.

The next big development was the manufacture of basic brick, both burned and chemically bonded. The burned brick had unusually useful characteristics. Foremost was its excellent spalling resistance, far superior to any burned magnesite or chrome-magnesite then marketed.

The new burned brick was excellent for electric furnace sidewalls both above and below the slag line. In a few years, most Canadian furnaces turned to this brick, and today it is still the principal product used in Canada for upper sidewalls.

In 1942, a new source of magnesite was discovered at Wakefield, Que. It had distinctly different characteristics from those of the Kilmar magnesites, which set Canadian researchers to work and led to a whole new group of refractories. Chief among the new materials was a burned magnesite brick with a high MgO content and a burned chrome-magnesite brick.

The new burned magnesite brick had an MgO content of approximately 85%. At the slag line, the new brick naturally resisted basic slags but stood up well even if the slag was occasionally acidic. Today this brick is generally used for this application.

The new chrome-magnesite burned brick was also followed by a chrome-magnesite chemically bonded brick and later by a magnesite-chrome unburned brick, all using Wakefield magnesite.

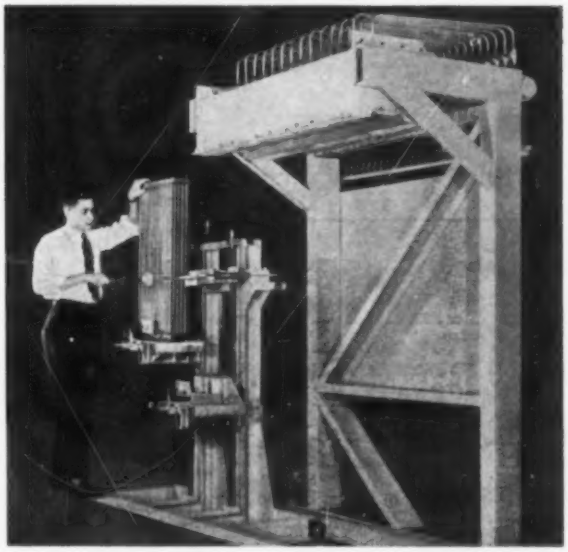
Chemically bonded magnesite-chrome has found favor in the upper walls of the electric furnace provided the brick are encased with steel. The development of steel-

the real cost of automatic heat processing

. . . here's how one SELAS installation stands up under that "long, hard look!"

This specially-designed, custom-built Selas machine silver-brazes pressure-tight joints on air conditioner coils — at production rates — without damage to easily-melted aluminum fins.

Yet heat input is sufficiently high to overcome, during the brazing cycle, the natural tendency of heat exchangers to draw heat away from joint areas. Previous torch method required four highly-skilled workers to equal machine's designed rate of output.



Employing automatic cycling and Duradiant® gas-air burners, this Selas machine silver-brazes tube return bends to copper tubes of aluminum-finned coils at rate of 30 coils per hour.

Labor Requirements

One worker operates this Selas Gradiation® brazing machine. Labor cost is now about 20c per coil. On a 2-shift-per-day basis, the saving in labor alone paid for this Selas unit in 3⅓ months!

Material Saving

Preplacing of preformed silver alloy rings for automatic brazing assures correct amount of brazing alloy. Hand-brazing invariably results in considerable excess fillets, wasting of costly alloy.

Material Handling

Since the Selas unit is actually a machine-tool type of equipment, it may be located advantageously within the entire production process.

Floor Space

Like all Selas automatic brazing machines, the unit is extremely compact, occupying only 4 feet by 8 feet of the assembly area.

Process Coordination

Selas designed and built this machine to meet *and keep pace* with definite production goals set by the manufacturer of air conditioners. Component by component, operation by operation—the machine is coordinated with the assembly-line type of production.

Temperature Control

Precise control of heat release rate and exposure time produces uniformly high quality brazing throughout 80 joints of each coil assembly.

Fuel Efficiency

Selas machine uses 200 cfh of natural gas, premixed with air by Selas Combustion Controller. Fuel cost is about ½c per coil. Any regular fuel gas can be used. Elimination of bottled oxygen and acetylene resulted in direct fuel cost savings sufficient to pay for Selas equipment in 4½ months!

Product Value

Using the workpiece value at time of brazing, the coils brazed in only 31 hours are worth more than the cost of this Selas machine!

Equipment Flexibility

Versatility inherent in all Selas automatic brazing machines makes possible the brazing of a variety of workpiece sizes with simple adjustment of fixtures. This machine handles assemblies up to 5½ feet high.

Automatic Operation

Once loaded, workpieces are carried automatically through the brazing cycle. All the operator does is load and push the "Start" button. He is free then to assemble the next coil while the machine completes the brazing.

Product Quality

Each of 80 joints is Selas-brazed tight and leakproof to withstand Freon pressures in excess of 100 psig.

Production Requirements

To keep pace with manufacturer's overall plant production, this Selas machine was designed and custom-built to braze 30 coils per hour. This rate matches production accomplished previously by 4 skilled workers.

Work in Process

At the rate of 30 coils per hour, only one coil is in process at any one time. This represents a 300% reduction in in-process inventory.

Human Element

The skills are built into the machine. Production of brazed coils with all joints pressure tight at rate of 30 coils per hour is not dependent upon ability, judgment or speed of the operator. Actually, the machine paces the operator.

Maintenance

Rugged, welded construction makes for easy, infrequent maintenance. Each machine is factory-tested under production conditions. Each machine is set-up and started-up under Selas supervision in the customer's plant. And, since no operating equipment is better than the service available, Selas stands ready, day or night, year round, to service its equipment on call.

* * *

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Refractories . . .

encased brick is very old and familiar to all steelmakers. The steel is an excellent thermal conductor and acts as a cooling system for the brickwork. This reduces spalling, but if some spalling does occur, the pieces are held intact. The steel also gives strength to the entire wall. However, when the original burned brick was steel encased, it gave even better results, so that most installations are of this burned, encased brick in upper walls.

Today's basic refractory practice in Canada parallels that of the United States in nearly all respects. Generally the sidewalls consist of steel-encased brick of the non-spalling burned variety, although several furnaces are using chemically bonded steel-encased brick in this location. Burned magnesite brick without plates is almost always used at the slag line. In plants where it is not used, burned nonspalling magnesite is installed without plates. No chemically bonded brick is used in this location.

Bottoms are usually built up of burned magnesite brick of any kind against the shell and covered with cold rammed MgO bottom material.

Chrome-magnesite is excellent for door arches and is widely used for them. Other brick used are steel-encased nonspall magnesite and steel-encased chemically bonded magnesite-chrome. E. C. WRIGHT

Prefabricated Openhearth Fronts

Digest of "Prefabricating New Fronts for Openhearth Furnaces Saves Time and Money", by A. E. Schoenebeck, Granite City Steel Co., Granite City, Ill. Paper presented at the 41st A.I.M.E. Openhearth and Blast Furnace Conference, Cleveland, April 1958.

AN INCREASE of 30% (or 1 million tons per year) in openhearth capacity was accomplished by Granite City Steel Co. without addition of new furnaces. A key element in this expansion was the replacement of the fronts of all seven furnaces; new fronts were needed to accommodate the largest charging boxes in the industry – 61 cu.ft. It was decided to prefabricate these new fronts in order to limit furnace downtime. Installation took 58 hr., a shorter time than that obtainable by any other method considered.

After making the buckstays and buying the required castings and structural steel, the parts were assembled into complete fronts at the extreme end of the charging floor. Each front was made for a furnace designated for general repair; when the furnace was down, the old front was removed after disconnecting all water lines and piping. Removal, including auxiliary work, took about 14 hr. The front wall was cut back one brick (4½ in.) to allow room for installation and alignment of the new front. This took about 2 hr.; five hours later, the new front was set and in its proper position. When castable refractory was poured into the new front and the wall, the most difficult part of the job was over, but the longest part remained. It took about 32 hr. to make all the piping and binding connections necessary for the front to be operative.

Although changing the furnace front lengthens the time for a general repair, much furnace availability has been gained by prefabricating. A general repair lasts about three days; with a front change too, the whole job takes 4 to 4½ days.
C.R.W.

Hardening Steel

Digest of "Mechanical Properties of Deformed Metastable Austenitic Ultra High-Strength Steel", by D. J. Schmatz and V. F. Zackay, Preprint No. 110.

THE STRENGTH LEVEL of alloy steel demanded by industry has steadily increased. The limiting factor to future improvements using conventional techniques seems to be the persistent problem of obtaining the desired increased hardness and strength without brittleness and notch sensitivity.

In this study, a new hardening technique applicable to most steels of high hardenability has been investigated. The process consists of plastically deforming metastable austenite in alloy steels at a subcritical temperature, where the austenite is relatively sluggish, and subsequently transforming the deformed austenite to a martensitic product.

The isothermal transformations of all the high-alloy medium-carbon steels are characterized by a separation of the pearlite and bainite transformation bands. Between these two bands is a region or "bay" where austenite is relatively stable for long periods of time. The "bay" area is convenient for accomplishing large amounts of deformation without forming isothermal decomposition products. Lesser degrees of deformation are possible at other temperatures, but time then becomes a critical variable. The deformation accomplished at temperature was limited to the "bay" area and the bainite range.

Alloy steels (Ni, Ni-Cr and Ni-Cr-Si) of varying carbon contents were processed using this technique. Mechanical properties were determined for various amounts of deformation, in the untempered condition and, also, after tempering at various temperatures. These properties are compared to those produced by conventional heat treatment of the same steels.

A summary of the results follows:

1. The critical amount of deformation required for a significant increase in mechanical properties is of the order of 25% reduction of area. The first 25% deformation is highly effective while greater amounts of deformation are diminishingly beneficial. Deformations as

Hardening Steel . . .

high as 75% did, however, continue to improve mechanical properties.

2. Substantial increases in ultimate tensile strength and elongation occur at low tempering temperatures. Ultimate tensile strengths in excess of 400,000 psi. with good ductility are obtained on highly deformed medium-carbon steels. Consistent with the increases in ultimate tensile strength, the hardness of the deformed material is substantially increased over that of the undeformed material. An increase in hardness of two to four points Rockwell C occurs with deformations ranging from 25 to 75%. The yield strength also increases due to deformation, although more scatter in the results occurs at low tempering temperatures.

3. Higher tempering temperatures decrease the ultimate tensile strength of the steels rapidly while increasing the yield strength at a lesser rate. Tempering temperatures in the range of 500 to 600° F. appear to be optimum for the steels employed in this study. Steels tempered in this range possess yield strengths in excess of 300,000 psi. with at least 6% elongation. At optimum tempering temperature, yield to tensile strength ratios are over 0.9. Higher tempering temperatures are also effective in reducing scatter in elongation data, and in considerably improving the ductility as measured by reduction of area.

4. Several suggestions are advanced for the mechanisms operative in this new hardening process. Decreased martensitic grain size, residual stress, increased dislocation density, preferred orientation, and very fine carbide precipitation are considered possible contributing factors.

D. J. GIRARDI

Degassing Bronze Castings With Nitrogen

Digest of "Improvement in the Mechanical Properties of Pronze Castings by Nitrogen Degassification", by P. K. Chakravarty and S. Visvanathan, *Transactions*, Indian Institute of Metals, Vol. 10, 1956-57, p. 119-130.

THE EFFECTS of occluded gases – principally hydrogen – on the properties of tin bronzes have been studied for many years. Several melting methods reduce the volume of hydrogen retained in molten metal. One of the most useful of these methods – since it can be carried out with a minimum of special equipment – involves bubbling dry nitrogen through the molten alloy. This method has the further advantage that it may be used with charges containing tin-bearing scrap without serious loss of tin.

In an experimental series, nitrogen at 0.75 psi. was blown through a ⅜-in. bore diameter refractory tube into slag-covered 500-lb. melts of bronze containing from 7.6 to 12.5% tin and 0.03 to 0.16% phosphorus. The melts were blown in a crucible which remained in the furnace after the gas fire was turned off. Temperatures were controlled within about ±15° C. (60° F.). At intervals during the blowing, 1-in. diameter by 8-in. long cylinders with an open 3-in. high head (vertical D.T.D. test pieces) were cast from the melts. This practice produced castings whose properties showed a consistent relationship to the blowing time. Such a relationship could not be achieved when the nitrogen was blown into a pouring ladle, or when using a horizontal test piece (B.S.S.L. 101).

(Continued on p. 184)

Degassing . . .

The density, ultimate tensile strength, and elongation were determined on pieces cast at the start and at intervals during the blowing until up to 25 cu.ft. of nitrogen had been blown into the melts. Initial densities varied widely with the amount of scrap in the particular melt. These densities improved to approximately 8.8 while the first 10 cu.ft. of gas was blown in. Thereafter the densities slowly approached the 8.88 theoretical maximum. The tensile strength and elongation also improved, but in most cases the improvement in these properties did not start to level off until about 17.5 cu.ft. of nitrogen had been blown into the 500-lb. melts.

The authors were able to take the data obtained in the manner just described and plot the density and the tensile strength after bubbling against the same properties before bubbling nitrogen through the melts. This resulted in a series of straight lines from which the improvement in properties to be expected from the use of a given amount of gas can readily be predicted. It is clear that there is a steady improvement in tensile strength and density with increasing quantity of nitrogen bubbled through the melt. (The elongation improved similarly.) Moreover, the level of properties obtained was found to be far in excess of that specified in existing standard British specifications for the corresponding tin bronzes.

WEBSTER HODGE

Oxygen-Sand Flame Cutting of Stainless Steels

Digest of "Oxygen-Sand Cutting of Chromium-Nickel Stainless and Stainless Clad Steels", by G. A. Ukolov, V. N. Chernov and N. N. Korf, *Automatic-heskaya Svarka,* No. 2, 1957, p. 89-92.

IT IS ALMOST impossible to make satisfactory cuts in stainless steel with the oxygen blowpipe commonly used for plain carbon steel. The infusible chromium oxide must be removed from the cut in some way. In the familiar powder-flux process, the

Flame Cutting . . .

flux, whose principal ingredient is iron powder, removes the oxide film from the kerf of the cut. The flux process is difficult to apply especially in re-starting a cut. The flux does not penetrate the layer of slag at the end of the interrupted cut. The flux process cannot cut thicknesses over ⅝ in., and irregular supply of flux to the torch causes instability in cutting. In this plant, the problems of mechanized flux cutting were overcome toward the end of 1952, but manual cutting was impossible due to instability of the process. Electric arc cutting also was tried.

Oxygen-sand cutting was perfected in this plant. In the sand process, the film of chromium oxide formed on the steel by the preheat flame is disintegrated by a jet of sand. The oxygen jet burns the metal thus exposed. The burnt or oxidized metal and molten sand form a slag that flows easily from the cut. The Moscow Technical College found that a 1:1 mixture of clean quartz sand and iron powder increased the productivity of the process compared with sand alone. The authors contend that sand alone is preferable and that the recommendation of iron-sand mixtures was based on tests with a powder-flux torch. The torches used at Moscow had a nozzle with circular apertures for the preheat flame which did not concentrate the heat.

The authors' apparatus utilizes a dispenser capable of handling high oxygen pressure and a relatively small cutting nozzle which delivers a concentrated jet of sand. The end of the nozzle is flame hardened for wear resistance. It is replaceable and is 0.091 to 0.099 in. ID. When the orifice wears to 0.16 in., it must be replaced. Torches have been in use 8 to 10 months without repair. The sand must be 100 mesh and free from clay.

Thanks to the stability of the process, the cut is of higher quality than with flux cutting. Welds often can be deposited on the cut surfaces without machining. Slag is readily removed. The low heat input causes less distortion than in flux cutting. Thicknesses from 3/16 to over 4 in. can be cut. A special torch with provision for supplementary oxygen from a separate cylinder is required

Flame Cutting . . .

for heavy plate. The width of the cut is:

Thickness	Width of Cut
3/16 to ⅜ in.	¼ to 5/16 in.
¾	3/16 to ¼
1¾	¼ to 5/16
4	⅜

The width may increase up to 1/16 in. as the orifice wears. Cutting speeds for Type 321 stainless steel range from 11 in. minimum for ⅜-in. plate to 7 in. minimum for 1 3/16-in. plate. The heat affected zone in 1 3/16-in. plate is only 0.002 to 0.016 in. deep for sand cutting, compared with 0.016 to 0.05 in. deep for flux cutting. The process requires the operator to wear a respirator and protective shield. The oxygen pressure is 57 to 100 psi. depending on thickness to be cut. After the sand orifice is opened, the oxygen and acetylene valves are turned on. Friction along the orifice walls brings the sand to a red heat, which ignites the fuel mixture. The oxygen-sand jet does not interfere with preheating. To start the cut, the supplementary oxygen valve is opened. The blowpipe should be inclined backward for maximum cutting speed on relatively thin material. Hole drilling is not recommended for the nozzle tends to clog.

Stainless clad steel with less than ⅛ in. of cladding can be cut with the ordinary cutting blowpipe. The sand process is used for thicker cladding. Clad steel up to 1¾ in. thick has been cut.

The over-all advantages of the sand process are stability of the cutting operation, the low cost of sand, the high productivity attainable compared with other processes, and the excellent quality of the cut.

G. E. Claussen

Ceramic Coatings . . .

(Starts on p. 111)

are two additional types. Their uses are expanding rapidly.

Coatings for low-carbon or low-alloy steels are basically cobalt-base ground coat. They are usually made by incorporating one hard ground coat and one low-firing ground coat with addition of about 25 lb. calcium alumina to 100 lb. of frit. The purpose of the low-firing ground coat is to seal off oxygen at low temperatures to prevent oxidation of the metal as the temperature is raised. After the coating has fairly well matured, the alumina takes over to form a refractory heat resisting coating. The coating resists by-products of combustion and minimizes oxidation in the range 1000 to 1400° F.

Well-established applications for this type are exhaust pipes for trucks and industrial installations where hot or corrosive gases must be carried. It is also being used for jet aircraft combustion liners, compressor blades and tank mufflers.

Stainless Type Alloys

A variety of coatings are used here. Most common are those developed for aircraft components known as National Bureau of Standards A-418. Many modifications are possible through addition of refractory materials. The Bettinger Corp. has developed some 50 variations with special characteristics. Some have good dielectric strength; others offer good fatigue and thermal shock resistance. Coatings are available which can be heated to 1700° F. and quenched in cold water for at least 10 sec. without damage.

Our Becote 12 and its modifications are used on aircraft engine components and a broad range of industrial items. Heating elements, exhaust pipes, tanks, automobile valves, retorts, trays for brazing, carrier belts and industrial furnace tubes are some of the applications.

NBS A-418 coating also has applications other than for aircraft parts. It is more flexible than Becote 12 but has somewhat less heat resistance. The safe operating level for A-418 coatings is 1600 to 1650° F. They may be applied as thin as 0.005 in. and still give protection.

The electronics industry is turning to ceramics for laminating small parts where insulation between the components is needed. Their good dielectric strength suits them well for many applications where insulation must withstand high temperature.

High Alloys

Both Becote 12 and A-418 are applied to most of the high alloys, but generally refractories are added to gain heat protection. Often high-firing cobalt enamels are used with a large amount of alumina. By using the appropriate refractory, the coating can be made either highly reflective or highly emissive. Reflective coatings turn back some of the heat which would otherwise reach the metal; emissive coatings help to dissipate heat from the metal. An outside reflective coating can reduce metal temperature by as much as 300° F.

Zirconium spinel and Treopax appear to be the best oxides for producing reflective coatings. These

Ceramic Coatings . . .

coatings must be applied in much greater thickness than ordinary high-temperature ceramics because they must be impervious to stray radiation from the base metal. Coatings with high emissive (low-reflective) values must be dark in color and must have a rough, matte surface. They are applied thin – usually 0.001 to 0.002 in. Refractories commonly used are nckel oxide, chromic oxide and ferrosilicon.

Refractory Ceramic Coatings

Much of the future for ceramic coatings lies in this area. Refractories not only increase thermal endurance but serve in other capacities as well. Typical super refractories for use here are the cermets, borides and nitrides. Zirconium boride melts at 3060° C., boron nitride at 3000° C.

The use of these ingredients with much higher melting points results in application problems because of firing conditions which must be employed. One answer to this problem lies in the use of powerful fluxing materials which, when properly incorporated into the coating, counteract the refractory ingredients without adversely influencing the performance of the coating. Potential fluxing materials include molybdenum trioxide, vanadium pentoxide, strontium and barium oxide and lithium compounds.

Basically, these newly developed types of ceramic coatings consist of three phases. Phase one is the standard high-temperature coatings, such as NBS A-418, Solaramic 5210-2c or Chicago Vitreous Corp.'s composition. Phase two introduces a refractory such as boron nitride. Phase three adds a fluxing agent, preferably a lithium compound. Most recent work has been aimed at converting the three-phase system into a two-phase one by eliminating addition of frits in the phase-one process. This can be done by using complex lithium compounds of glass-like nature.

The use of highly refractory materials with fluxing agents opens up the possibility for creating entirely new types of ceramic coatings with properties which will answer some of today's most stringent requirements.

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R. A. Gray
Editor

(Seal)

Sworn to and subscribed before me this 30th day of September, 1958.

Charlotte T. Finley
Notary Public

(My commission expires May 20, 1960.)

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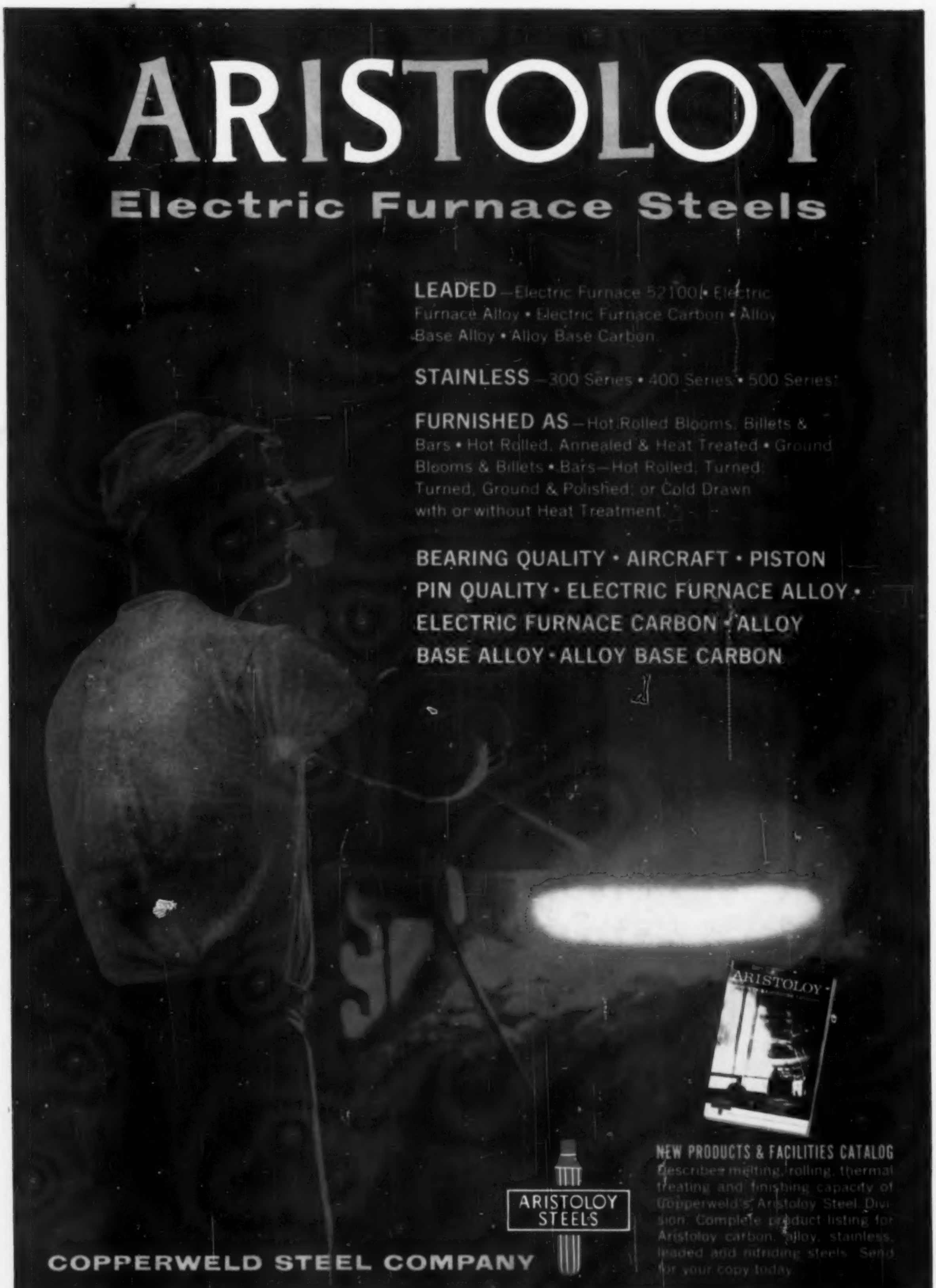
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